Page No. 1-7- are missing

Certainly the present system will produce a group of uniformly well-trained orthopaedic surgeons of moderate ability, and some of more than average ability will emerge from the assembly line. On the other hand, orthopaedic surgery will suffer because of this uniformity, and many men will have been forced to submit to courses of training which were unsuitable answers to their problems; while others who might have become outstanding orthopaedic surgeons will be denied the privilege of entering this specialty, because they did not decide to adopt it before or shortly after finishing medical school. They properly waited until their judgment was more mature. By this time they had developed skill in general surgery or general medicine for which they could get no credit from our Board, or they had incurred obligations which prevented them from starting all over again and devoting three full years to so-called formal specialized training.

From what has been said, one may infer that I believe that our present program may actually be hindering, rather than contributing to, the advance of our specialty. From time to time we should examine critically our requirements for certification, in order to determine whether or not our plan is functioning in a manner which is satisfactory to us. I submit the following:

1. We should study modern methods of examinations, especially those developed in the Army and, if necessary, should seek the aid of psychologists. We can devise comprehensive examinations which will be real tests of a man's ability. With such examinations it would be possible to be less rigid in the requirements for preliminary training. It is to be emphasized that we owe more to the candidates than they owe us. In planning the examinations, it should be recognized that the orthopaedic surgeon is a surgeon who largely limits his work to the spine and extremities, and it is the function of the Board to determine whether or not the candidate's knowledge and ability are such that he can be classified as an expert in this field. His qualification to practise medicine has already been determined by his state or the national board of medical examiners. Uniform examinations in anatomy, physiology, pathology, biochemistry, and bacteriology, to be taken by the candidates for certification in general surgery and in all of the surgical specialties, are not suitable for the purpose intended.

Such examinations would be planned largely to test the candidate's knowledge of general surgery, and would not test his proficiency in orthopaedic surgery. While the term general surgeon may be taken as referring to a general practitioner of surgery, who is justified in performing any type of surgical procedure, it is a fact that in areas in which the various surgical specialties are adequately covered, the general surgeon largely limits his practice to the abdomen, breast, front of the neck, and the subcutaneous tissues. It is thus evident that his field is more restricted than is that of the orthopaedic surgeon. We must abandon the delusion that the modern general surgeon is proficient in all of the surgical specialties. It is obvious that each surgical specialty should conduct its own examinations and is capable of determining whether or not a man is qualified to practise that surgical specialty.

2. We should revert to our original function of establishing minimum requirements for the practice of orthopaedic surgery and should avoid even the appearance of attempting to dictate the future development of our specialty. With this in view we should abolish the requirements of certification for membership in our orthopaedic societies. We should also discourage hospitals and government agencies from discriminating for or against an orthopaedic surgeon because he has or has not been certified by the Board.

We may lessen the number of candidates for examination, but we will improve the quality and will tend to eliminate the rapidly increasing throng of half-baked young orthopaedic surgeons whose only claim to fame is that they are "certified", and who, having attained that enviable position, can look down on their less fortunate brethren and from now on can rest on the laurels gained by six years spent in pursuing the course prescribed. If left to follow their own inclinations in their desire to perfect themselves in

orthopaedic surgery, how many of these men would have pursued the same or a similar course? Is it not likely that some of the more adventurous spirits would have deliberately or casually left the beaten path for a while and wandered into the territory allotted to allied branches of medicine or related sciences? And when they returned, laden with the fruits of their labors in other fields, would this increment be harmful to orthopaedic surgery? Our specialty needs all of the outside help that it can get, and we should welcome men who are learned in other branches of medicine. As we narrow and lengthen the road, we progressively lessen the expansion of our specialty and its ability to serve mankind.

3. This brings me to a subject where there is room for wide divergence of opinion,—namely, the minimum requirements for training before a candidate can be accepted for examination leading to certification. It is my impression that we have been too rigid in our insistence that candidates fulfill the requirements as regards preliminary training. We should demand evidence that the candidate has devoted sufficient time to the study and practice of orthopaedic surgery, so that he may reasonably be expected to have acquired a satisfactory knowledge of the subject and sufficient skill in the technique of orthopaedic procedures to enable him to practise his specialty with safety, and to have developed adequate maturity of surgical judgment and scientific integrity to warrant his being entrusted with the orthopaedic problems arising in his community. The candidate should then be subjected to a searching examination, in order to determine whether or not he has profited sufficiently from his study and experience to merit the stamp of approval.

We should cultivate broadness of mind in giving credit for the work done in other branches of medicine or surgery or of allied sciences, and in this way attract to our specialty men who have something more to contribute than their knowledge of orthopaedic surgery. Likewise, they should not hesitate to give ample credit for years of experience in the practice and teaching of orthopaedic surgery in recognized clinics or hospitals or in association with orthopaedic surgeons of known ability. The function of the Board is to determine whether or not the candidate possesses the minimum requirements for an orthopaedic surgeon, and it should not be too greatly concerned about how this ability was acquired. We should eliminate the requirement that a candidate rigidly apportion his time among adult and children's orthopaedics and fractures, and especially should we abandon the required six months spent in reviewing the fundamental branches of medicine, presumably in their relation to orthopaedic surgery. I know of no place where such a course can be obtained and, if it is ever offered in a medical school, it will be a super-quiz course; and those who take it will have wasted time in acquiring a mass of ephemeral knowledge, which could have been spent more profitably in research or in clinical work.

The candidate should know that he will be examined in the anatomy and pathology of his specialty and that he may be asked questions involving knowledge of other fundamental sciences; and he will attempt to increase his knowledge of them as he pursues his orthopaedic education. To demand that an orthopaedic surgeon forsake his practice and spend six months cramming fundamental sciences into his brain is certainly verging on the ridiculous.

I am convinced that regimentation of postgraduate medical education in the specialties is a mistake. No one specific course of study or hospital training is suitable or desirable for all men who are to engage in the practice of orthopaedic surgery. If I were to attempt to lay out a course for a hundred such men, I would start in high school and see that, in addition to their regular studies, all were given a fairly comprehensive course in manual training, in order that they might learn to use their hands and acquire knowledge of and respect for sharp tools.

All would enter college and about half of them would continue until graduation. These would take a variety of courses: some, science; some, engineering; some, the classics; some, humanities; and some, business administration with enough science to meet the entrance requirements of the medical school of their choice. An effort would be made

to stimulate each student to develop especial interest in one or two subjects, perhaps not related to medicine, during the last two years of college. About a fourth of these would spend a year in graduate study before entering medical school, another fourth would work for a year or so, and the others would enter at the next term after graduation from college.

The other half, largely because of limited financial resources, would spend only two or three years in college. Their object would be to fulfill the entrance requirements to medical school and to acquire as adequate a general education as possible within the time allotted. This heterogeneous group would then complete the regular course leading to the degree of Doctor of Medicine in a Class A medical school, and each of them would then serve a one-year internship in surgery; about half of these would then begin their orthopaedic training and would serve for one or more years in an orthopaedic service where the visiting staff were conscious of their obligation to train the resident staff.

Of the other fifty who had completed one year in general surgery, about half would continue in this field for from one to four years longer before beginning their orthopaedic training. The other twenty-five would interrupt their surgical training at this point and spend a year or more in study and research in general medicine or preferably in one of the fundamental branches of medicine. The members of this group would then begin their orthopaedic training two or more years after graduation, and they too would serve one or more years in a satisfactory orthopaedic service.

We now would have a group of young men, all of whom have had one-year internships in general surgery and one-year internships in orthopaedic surgery, and half or more of whom have spent from one to five years additional in training in general surgery or in work in some other branch of medicine. It would be recommended that all of these men spend a second or possibly a third year in an orthopaedic service where they could be given more responsibility and gain more experience, but this would not be required. Some of them would enter practice in association with more mature orthopaedic surgeons; some would enter practice directly and continue to add to their knowledge by study and attendance at medical meetings; some would take full or part-time positions and continue to work in out-patient clinics, and gradually would be entrusted with the care of in-patients and with teaching in established orthopaedic centers.

In this manner, we would obtain a hundred orthopaedic surgeons with wide variation in general and special education and a group which would compare favorably with our present membership.

I would also not fail to recognize the fact that a good general surgeon can develop into a good orthopaedic surgeon by simply directing his energies to that field. Likewise, a young man with training only in general surgery may, by study and association with a good orthopaedic surgeon, become highly skilled in this field. In neither case is any formal orthopaedic training necessary. Would I perhaps be going a bit too far if I even suggested that it is possible for one to practise general surgery and yet be an excellent orthopaedic surgeon, and to voice the opinion that certain general surgeons merit qualification as orthopaedic surgeons, just as some orthopaedic surgeons are excellent general surgeons?

In view of the foregoing, I suggest that we alter radically our policy of demanding that a candidate follow a rigidly outlined course of orthopaedic training, and that we recognize the incontrovertible fact that satisfactory orthopaedic surgeons have been and can be developed in many different ways. Our standards of excellence should not be lowered, and we can demand more time devoted to practice; however, we should not close the door of our specialty in the face of men who are well qualified, but whose education has not been along the lines of regimentation.

SURVIVAL IN BONE SARCOMA*

BY HARRY PLATT, M.S., F.R.C.S., F.A.C.S., MANCHESTER, ENGLAND

Professor of Orthopaedic Surgery, University of Manchester

Most of our general and statistical knowledge regarding prognosis in the various types of bone sarcoma is derived (1) from figures published by the Registry of the American College of Surgeons between the years 1934 and 1939, inclusive; and (2) from such individual contributions as those of W. B. Coley (1933 and 1934), Campbell (1935), B. L. Coley (1938), Meyerding (1938), Simmons (1939), and more recently Macdonald and Budd (1943). Analyses of the not inconsiderable number of cases classified as "long survivals" (patients living five years or more), recorded by the Registry or in the personal studies of the writers already mentioned, permit us to draw certain broad conclusions concerning the effectiveness of various methods of treatment.

The case for the surgical eradication of accessible tumors as the treatment of choice is in my judgment fully proven. The value of postoperative treatment by means of toxins or irradiation or both seems to be still *sub judice*, but these therapeutic agents should not be withheld from a patient if circumstances permit their systematic use.

It can now be said that the outlook in the case of *osteogenic sarcoma* is not so gloomy as it appeared at one time. Of the various histological types, the *spindle-cell sarcoma* (fibrosarcoma) would appear to be the least malignant form, but the evidence regarding the degree of malignancy of the *chondromyxosarcoma* is conflicting. The *extraperiosteal sarcomata*, in my experience, are also tumors of varying malignancy. Of the thirty-two cases in my own collection, six appear in the group of five-year survivals, and seven in the list of short survivals (under two years). All authorities are agreed that the outlook in the *Ewing* tumor remains grave, despite its ready response to irradiation. In this connection, it is important to note that thirteen of the fourteen five-year survivors with this tumor, recorded in the Registry report of 1939, had been treated by surgical measures. These general facts must determine the advice we offer to our patients. But the problem of survival in bone sarcoma still remains an enigma, for so far there has been a failure to elicit any significant evidence concerning the influence of various factors which might possibly have a causal relation to this phenomenon.

I have recently submitted my own modest collection of 161 sarcomata to a scrutiny on the lines laid down by Bradley Coley and Pool in their most valuable paper, published in 1940. An analysis of my series reveals twenty-three five-year survivals. Twenty-two of these patients, treated by radical operations, are fully proven cases, but in one—a pelvic sarcoma—proof from biopsy was not forthcoming.

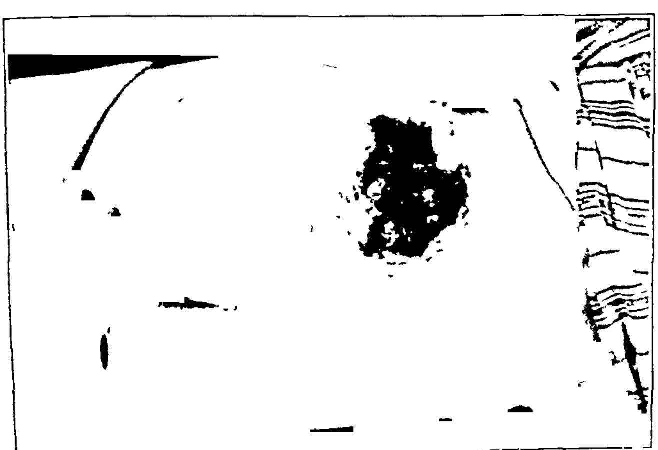

FIG. 1-A

The main details are presented in Table I.

Among these twenty-three cases were two patients with pelvic sarcomata treated by hindquarter amputation; the survival period for one was five years, and the other is still

* From a paper read before the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1946.

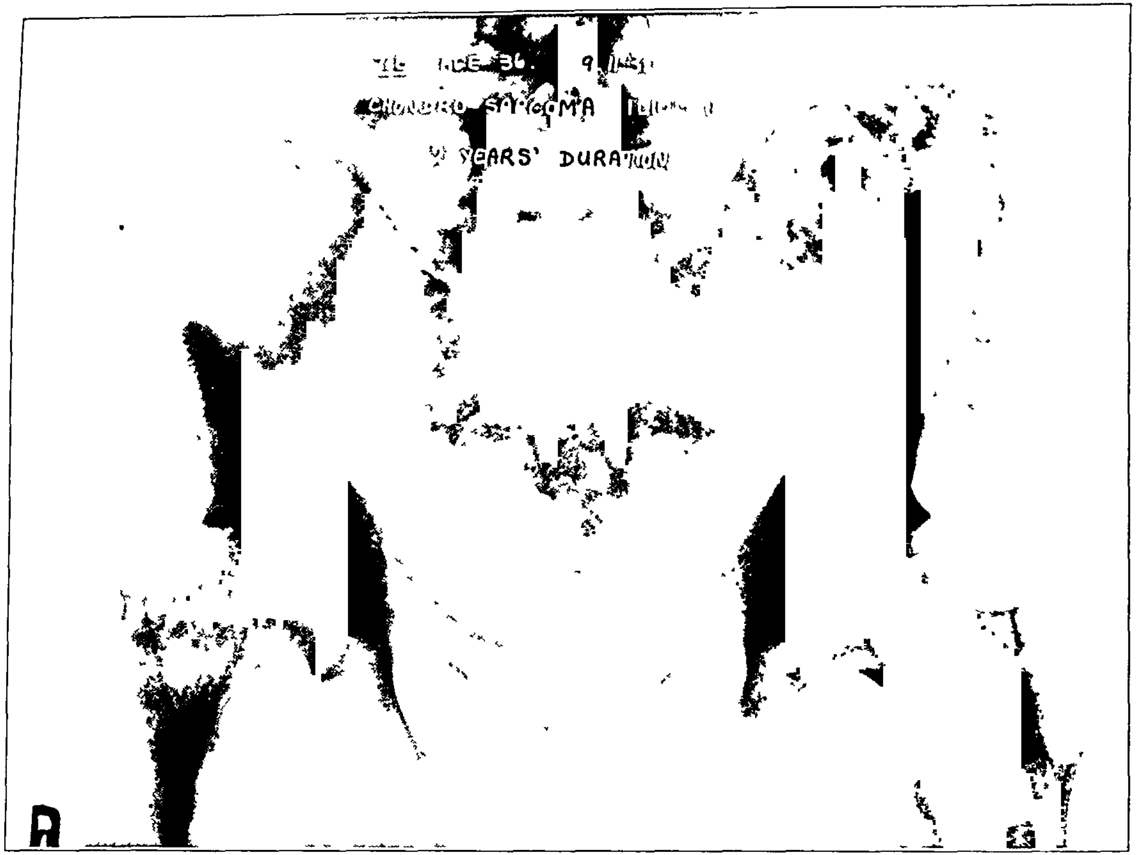

Fig. 1-B

Fig. 1-C

T. B., male, aged thirty-six years, had osteogenic sarcoma (chondrosarcoma) of the left ilium.
Fig. 1-A: Shows the large sloughing area, following treatment by irradiation for two years.
Fig. 1-B: Roentgenogram shows condition of the ilium at this time (November 9, 1938). Hindquarter amputation was performed in December 1938. The man is alive and well, seven years later.
Fig. 1-C: Drawing of the specimen obtained at operation.

living (in June 1946) after seven years (Figs. 1-A, 1-B, and 1-C). Eight patients in this series survived more than ten years,—five of these had osteogenic sarcomata; two, extra-periosteal sarcomata; and one, a sarcoma arising in a chondroma (Figs. 2-A and 2-B).

I have attempted, without success, to set this series of twenty-three long survivals over against a series of short survivals (under two years) of which my collection affords forty-nine examples, in the hope of discovering a clue to the mystery of long survival. In this comparison, I have found that no significance can be accorded to such factors as age, sex, site of tumor, and the duration of symptoms before the tumor was eradicated, the latter being a point notoriously difficult to estimate accurately. (See Figures 3-A, 3-B, 4-A, and 4-B.) Forty-one patients in this series of short survivals died within a year after operative treatment. At first sight this is a melancholic picture, but when we consider that, in 128 accessible tumors treated by radical operative procedures, seventy-nine patients have survived over two years, and twenty-three of these five years or more, the current view, that the general outlook in bone sarcomata as a whole is by no means tragic, is reinforced.

I have been unable to use the Coley toxins systematically, either following operation or in inoperable tumors, so that I have had no opportunity of estimating the part they may play in determining survival.

I believe that in the combination of radical operation and some systemic agent, still to be discovered, lies the hope of potential cure or still longer survival in this field of malignant disease. Irradiation is admittedly a useless form of therapy in the tumors of

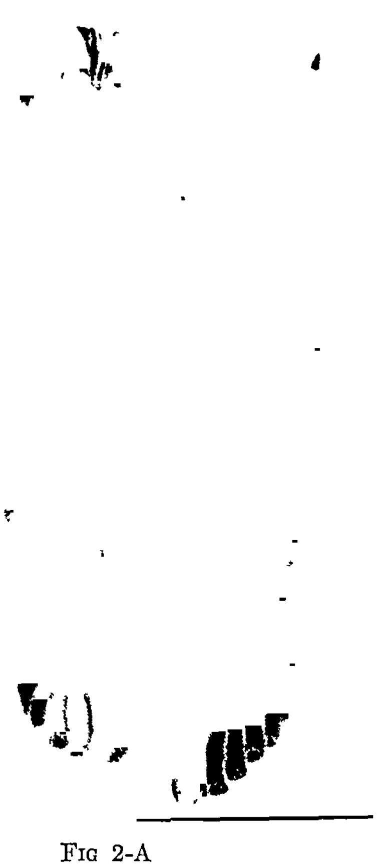

Fig 2-A

Fig 2-B

R. C., a boy, eleven years old, had osteogenic sarcoma of the upper end of the left tibia
Fig. 2-A: Shows condition of knee before operation.
Fig. 2-B: Roentgenogram showing large osteolytic tumor involving the metaphysis of the upper end of the tibia. Amputation was performed January 13, 1936, and a regular course of Coley's toxins was given during the three years immediately following amputation The boy is living and well, ten years after operation.

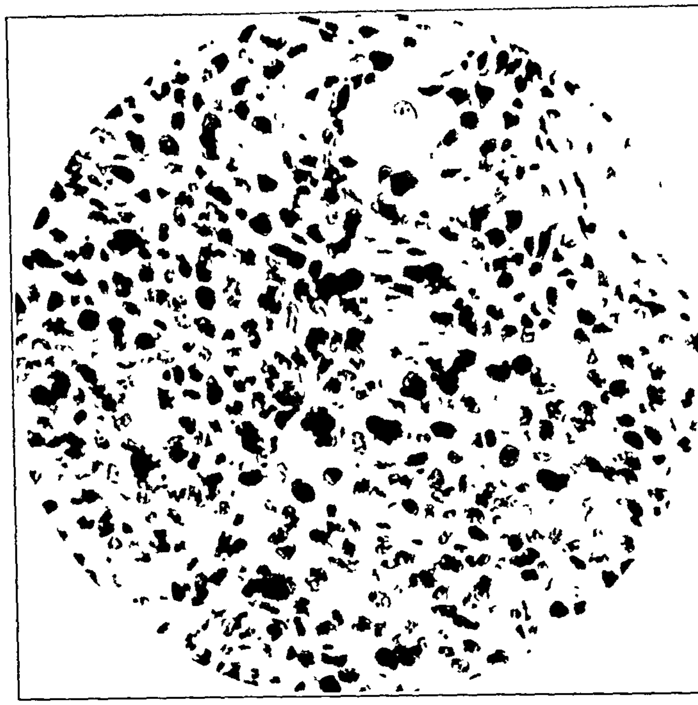

FIG. 3-A FIG. 3-B

H. R., male, aged twenty-three years, had osteogenic sarcoma of the upper end of the left fibula.
Fig. 3-A: Shows amputated specimen.
Fig. 3-B: Photomicrograph showing that the predominant cell was oat-shaped. The man died eighteen months after amputation.

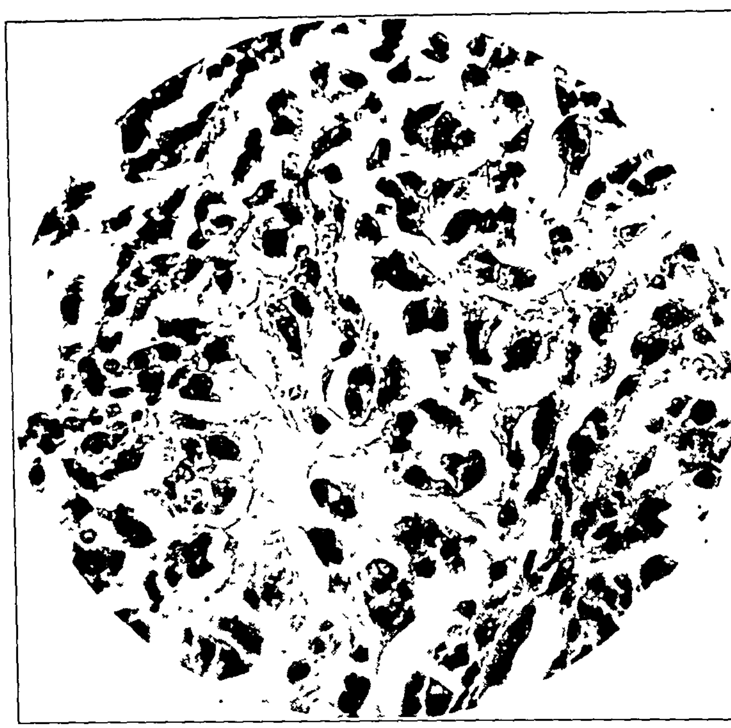

FIG. 4-A FIG. 4-B

K. P., male, aged twenty-four years, had osteogenic sarcoma of the upper end of the right fibula.
Fig. 4-A: Shows amputated specimen (compare with Fig. 3-A).
Fig. 4-B: Photomicrograph shows that the predominant cell was oat-shaped. Patient is living, thirteen years after amputation.

the osteogenic-sarcoma group. My own slender experience with the Ewing tumor has not convinced me that irradiation before amputation, or irradiation alone in accessible tumors, has any material influence on the ultimate fate of the victims of this most lethal type of bone tumor.

TABLE I
LONG SURVIVALS (5 YEARS AND OVER)

Type of Lesion	No. of Cases	Totals
Osteogenic sarcoma		
Sclerosing	0	
Osteolytic	5	
Chondromyxosarcoma	8	13
Sarcoma in abnormal bones		
Fibrocystic disease	1	
Benign osteochondroma	3	
Paget's disease	0	4
Extraperiosteal sarcoma		6
Ewing's tumor		0

Age of Patient at First Treatment	No. of Cases	Survival Periods	No. of Cases
Under 20	4	5 to 9 years	15
20 to 40	12	10 to 15 years	6
40 and over	7	16 to 20 years	2

TABLE II
SHORT SURVIVALS (UNDER 2 YEARS)

Type of Lesion	No. of Cases	Totals
Osteogenic sarcoma		
Sclerosing	4	
Osteolytic	23	
Chondromyxosarcoma	6	33
Sarcoma in abnormal bones		
Paget's disease	4	
Osteochondroma	1	5
Extraperiosteal sarcoma		7
Ewing's tumor		4

CONCLUSIONS

A study of a series of twenty-three five-year survivals when compared with a series of forty-nine short survivals (under two years) fails to reveal any outstanding or significant factors which would determine the prognosis in the sarcomata of bone.

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DISCUSSION

Dr. D. B. Phemister, Chicago, Illinois. It has been most stimulating and interesting to hear this presentation of Professor Platt's on bone sarcoma, based on his careful study of a large series of cases.

He spoke of the appearance of bone sarcoma in bones that have been the sites of previous changes. The occurrence of sarcoma in bone that has been irritated might be mentioned. At the last meeting of this Association, Dr. C. Howard Hatcher reported three such cases. Because of the known appearance of sarcoma in the skeleton after radium ingestion, it is certain that uranium and plutonium ingestion will predispose to the same development.

About benign giant-cell tumors, I think we are quite generally agreed in this country that surgery is the best form of treatment. Personally, I feel that amputation should rarely be done, but instead the more extreme cases should be treated by resection and bone transplantation.

As to the classification of bone sarcomata, I feel that in some cases one should be satisfied with the diagnosis of sarcoma and not be too much concerned about the type of cell or tissue. However, a knowledge of the cell or tissue type is desirable, since it may aid in the selection of the best form of treatment. In recent years, the use of large blood transfusions has made it possible to do very extensive resection of bone and soft parts at the tumor site and to repair the skeletal defect by massive bone transplantation, without risk of circulatory failure, and penicillin cuts down the risk of infection and loss of the bone graft. This makes excision possible in certain favorable cases and avoids amputation. From the standpoint of classification, the most favorable types of sarcoma for resection, in our small series of cases, have been chondrosarcoma and sarcoma arising in giant-cell tumor of bone. Four chondrosarcomata have been excised and replaced by bone grafts, and the patients have survived from six to twelve years without regional recurrence or metastases. Likewise, two patients with sarcomata developing in benign giant-cell tumors have remained well, one for five and one-half, and one for eleven years following excision. Osteogenic sarcomata, regardless of how small they were at the time of operation, have shown a marked tendency to make distant metastases and to recur locally. However, in one classical case of sarcoma of the upper humerus which was ossifying markedly, the patient is well, with a useful arm, ten years after resection and transplantation. One patient with a Ewing's sarcoma of the femur, treated first by x-ray and then by resection of seventeen centimeters of the shaft, is alive and free from recurrence six and one-fourth years after operation.

Dr. Philip D. Wilson, New York, N. Y.. It is a great pleasure to be allowed to say something in the discussion of Mr. Harry Platt's paper. He is an old friend and one whom I have seen work and one whose work I value very highly. I have been very interested in his remarks, which I think are very informative and stimulating. I think his first point on the responsibility of the orthopaedic surgeon in the care of these cases is a very important one. I am very happy I can make this remark with Dr. D. B. Phemister, who is a professor both of surgery and of orthopaedic surgery, preceding me in the discussion. I know in several centers there are excellent general surgeons caring for these patients and doing excellent work, yet I know of one instance not long ago where a Brodie's abscess was explored under the diagnosis of neoplasm. It needed exploration, it was the proper thing to do; but it seems to me a knowledge of bone lesions or bone pathology is necessary and certainly will help in the diagnosis. I think these men who are treating tumors will invariably have brought to their clinics a great many cases of non-neoplastic conditions, which represent bone anomalies of various types which require orthopaedic care. They will undertake their treatment, when they are not properly qualified for it. I am sure there are many of these lesions where local excision could be done, if the surgeon had a knowledge of the proper reconstruction of bone.

I am very interested in Professor Platt's classification, which is simple and desirable. I would like to tease him a little bit by asking him where he has put osteoid osteoma. I have had the experience of finding it may still be classified as a bone tumor. Again, he excludes from his classification eosinophilic granuloma which, of course, is a questionable diagnosis. We have the feeling that that is a part of a more generalized disease, involving the lipoid and cholesterol metabolism; but I would like to hear Professor Platt's comment on that lesion.

In cases of abnormal bone, I am inclined to feel that the percentage given of five to ten per cent for the development of osteogenic sarcoma is high. I am sure we are seeing a great many more cases of Paget's disease than formerly, this is largely due to better diagnosis. The localized forms, in which Paget's disease may be confined to a single bone or one or two bones, as well as the generalized cases, are met with. I have had the experience of seeing osteogenic sarcoma in only two cases of Paget's disease, and both have been rapidly fatal. Another condition in which we may see the development of osteogenic sarcoma is chondrodystrophy. I have such a patient, who has survived ten years following excision of the upper end of the femur. I had the unfortunate experience of having to take care of a girl with radium poisoning from emanations in the expired air, in whom osteogenic sarcoma developed. I would like to ask Professor Platt whether he has had experience or whether he cares to make any comment on the A C S. serum of the Russians.

Dr. Henry W. Meyerding, Rochester, Minnesota: Professor Platt, it has been a great pleasure to be here and take part in the discussion of your paper. We, as surgeons, are interested in the distinction between benign and malignant lesions of bone, and it is good to see that you have microscopic proof to verify your findings. In 1938 I read a paper on osteogenic sarcoma before the American Medical Association, in which the degree of malignancy of this lesion was graded; I had hoped that you had graded the degree of malignancy in your cases, for knowledge of the grade is of vital importance in deciding the type of treatment to be used. In our series of cases, the patient who had a Grade 1 osteogenic sarcoma did not undergo amputation; whereas among those patients who had Grade 3 or Grade 4 osteogenic sarcomata, the percentage of amputations was high.

The responsibility of early diagnosis rests primarily with the physician who examines the patient first. Later, when the surgeon is called in consultation, he must first exclude pulmonary metastasis, by means of roentgenographic examination of the thorax. We make roentgenograms of the thorax routinely in our cases of tumors of bone. Time and time again I have seen a young patient with a tumor that was not very large; yet I have been amazed by the fact that metastasis to the lungs had already developed. That occurred twice in one day this summer.

Having obtained the history, roentgenographic and laboratory observations, the physician nevertheless may not be able to determine the character of the lesion until he has had resort to biopsy. I am pleased to learn that Professor Platt believes in biopsy. I do not believe in needle biopsy, but prefer that which includes incision, inspection of the tumor, and removal of an adequate portion of tissue for pathological examination. I believe, furthermore, that even though microscopic section and examination and roentgenographic examination are employed, the true character of the lesion may not be known until metastasis or death has occurred. This is a well-known fact. A careful follow-up record in the study of these cases of tumors of bone is very important. These studies are very important; for instance, this summer a patient whom I had first seen many years previously came in to see me. Twenty-six years ago, I had performed for this patient amputation of a leg, through the lower part of the femur, because of a malignant tumor. This man never had answered any of my inquiries concerning his state of health, and I had decided that he was not living. He came back because he had become alarmed at the possibility of recurrence; but we were most pleased to find that his fears were groundless.

In closing, Professor Platt, I will say again that it is a very great pleasure to have you with us, and I appreciate the opportunity of taking part in the discussion of your paper.

Mr. Harry Platt, Manchester, England (closing): About Dr. Phemister's and Dr. Wilson's remarks that metastases preclude the carrying out of resection rather than amputation, I have had little experience with this heroic attack, but I feel now that this line of attack is wiser.

About the eosinophilic tumor that belongs to bone-marrow disease, I do not know.

I do not know anything about the Russian serum. I have heard of it, but I do not know it.

Dr. Meyerding spoke about the grading of malignant tumors, which for many years, in other tumors, has been one of the great achievements of the Pathology Department of the Mayo Clinic. We have not followed that analysis at all, so I cannot say very much about it. I am glad he is a wholehearted supporter of real biopsy and real exposure and removal of tissue. I wish to emphasize once again that I think these tumors, benign and malignant, belong to the skeletal tissues and are, therefore, part of the essential field of modern orthopaedics. Their careful documentation in various clinics is all-important. It is just as important as, if not more important than, study made in an impersonal way on material collected in the literature.

COMPLICATIONS OF FRACTURES OF THE NECK OF THE FEMUR *

BY H. B. BOYD, M.D., AND I. L. GEORGE, M.D., MEMPHIS, TENNESSEE

From the Willis C. Campbell Clinic, Memphis

It is the purpose of this paper to present the complications and end results of internal fixation of 300 acute central fractures of the neck of the femur treated by the Staff of the Campbell Clinic. Smith-Petersen nails were used in 285 of the hips and Knowles pins were used in fifteen. All impacted fractures and fractures of the base of the neck were excluded, only Pauwel[1,2] type II and III fractures being included. In all cases, one year or longer has elapsed since operation.

This is not a consecutive series; none of the patients treated at John Gaston (City) Hospital were included, and most of those treated in the other hospitals in the city were not included, for the reason that roentgenograms on file at the Clinic were inadequate. From a practical standpoint, however, the series may be considered a consecutive one, as the cases were unselected and were consecutive with respect to available and adequate clinical and roentgenographic data. The study includes the early cases on record at the Clinic and was arbitrarily limited to 300 hips, that statistics might be based on an even number.

These 300 fractures of the femoral neck were observed in 294 patients. In none of the six bilateral fractures were both hips injured simultaneously; the shortest period between fractures of the two hips was one year and eight months, and the longest two years and nine months.

TABLE I

MORTALITY

Age	Number of Hips	Deaths	
		Number	Per Cent.
Under 40	15	0	0
40-59	50	0	0
60-69	92	5	5.4
70-79	87	9	10.3
80-96	56	14	25.0
Total	300	28	9.3

Of the total number of deaths, twenty-one occurred in less than four weeks after operation, and seven, within four weeks to six months after operation.

The mortality for the various age groups is indicated in Table I, the overall mortality being 9.3 per cent. There were twenty-eight deaths following the 300 operations, twenty-one of these having occurred within the first four weeks. This is believed to represent the true operative mortality. Seven deaths were recorded from four weeks to six months after operation. Undoubtedly, a number of other patients, whom we were unable to trace, died within the period of four weeks to six months after operation. It is of interest that all of the patients who died were over sixty years of age, and that the mortality increased with age until it reached 25 per cent. in the ninth and tenth decades.

The postoperative follow-up of 131 of the fractures was less than one year (Table II). Over 80 per cent. of the patients treated at the Clinic came from out of the city, and several factors—such as advanced age, poor general health, insufficient funds, or difficulty in se-

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1946.

TABLE II

Follow-Up Study

Period	Hips	
	Number	Per Cent.
Less than 1 year	131	43.7
1–2 years	98	32.7
Over 2 years	43	14.3
Deaths	28	9.3
Totals	300	100.0

curing transportation during gas-rationing—prevented follow-up visits. An additional 141 were followed for one year or longer. Bony union took place in 86.5 per cent. of the hips, the bone failing to unite in the remaining 13.5 per cent. (Table III). The majority of patients should be followed for at least a year to determine with certainty whether or not bony union has occurred. In patients of the younger age groups, definite bony union may be seen in the roentgenograms within less than a year. Frequently, however, mistakes will be made if one endeavors to determine the presence of union under one year. Occasionally, bony union develops after a year, especially in patients with gradual absorption of the neck of the femur. In ten of the nineteen ununited fractures, poor reduction, inadequate mechanical fixation, premature removal of the nail, or a combination of these factors contributed to the non-unions. The remaining nine ununited fractures followed satisfactory reductions and nailings; two of these were in patients with Paget's disease involving the head and neck of the femur.

The number of hips showing aseptic necrosis and degenerative arthritic changes following bony union is shown in Table IV. It is a coincidence that the percentage of aseptic necrosis and arthritic changes in the hip each happens to be 33.6 per cent., as all patients with aseptic necrosis did not have arthritic changes, whereas a few without aseptic necrosis did have arthritic changes. The majority of those with aseptic necrosis had arthritic changes; and, in all probability, all patients with aseptic necrosis will eventually have arthritic changes if weight-bearing is carried out over an appreciable length of time. The incidence of aseptic necrosis seen in patients studied one to two years is essentially the same as that observed in patients studied two years or longer. In the latter group, aseptic necrosis was apparent in the roentgenograms before the elapse of two years. This indicates that aseptic necrosis can be detected within one to two years following the fracture.

The arthritic changes in the head of the femur were classified as 1, 2, 3, and 4, plus. Slight roughening of the head of the femur was rated as 1 plus. A slight depression and irregularity of the head of the femur were classified as 2 plus. Moderate but definite collapse of the head was classified as 3 plus, while marked collapse of the head was classi-

TABLE III

Bony Union

Age	Union		Non-Union	
	No. of Hips	Per Cent.	No. of Hips	Per Cent.
Under 40	11	100.0	0	0
40–59	31	91.0	3	9.0
60–69	42	78.0	12	22.0
70–79	23	92.0	2	8.0
80 and older	15	88.0	2	12.0
Totals	122	86.5	19	13.5

FIG. 1-A FIG. 1-B

Fig. 1-A: Acute fracture of the neck of the femur in a woman, forty-seven years of age.
Fig. 1-B: Appearance of the bone approximately six months following insertion of the Smith-Petersen nail.

FIG. 1-C

Anteroposterior and lateral roentgenograms, taken nine and a half years following the insertion of the Smith-Petersen nail. The patient has an excellent result, without aseptic necrosis or arthritic changes.

fied as 4 plus. In Table IV, 1 and 2 plus arthritic changes have been listed as moderate; 3 and 4 plus arthritic changes have been listed as severe. Clinically, the patients with moderate arthritic changes have been able to tolerate the pain in the hip for a restricted

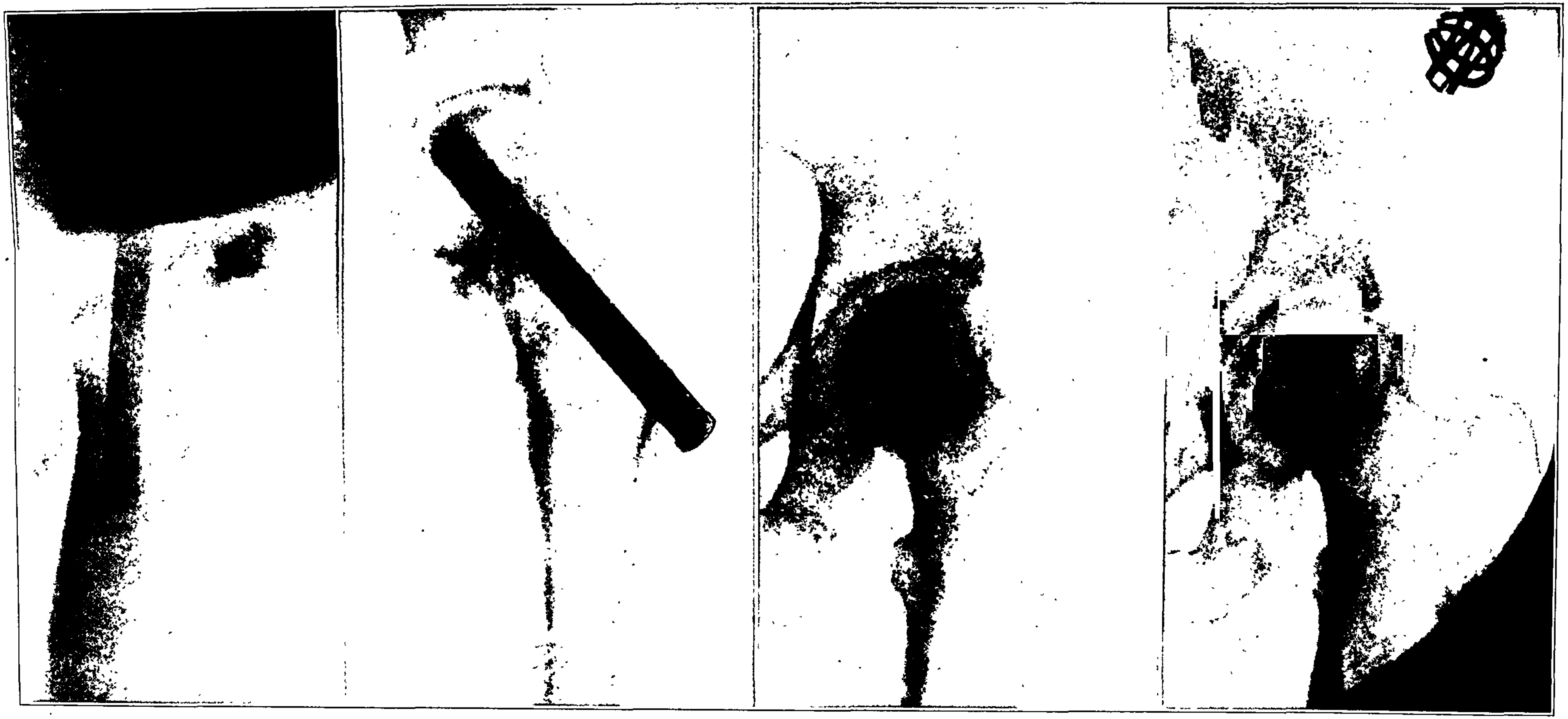

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 2-D

Figs. 2-A and 2-B: Lateral and anteroposterior views showing position of the Smith-Petersen nail approximately six months following the fracture of the neck of the femur in a woman, fifty-four years of age.

Fig. 2-C: Appearance of the hip twelve months following insertion of the Smith-Petersen nail.

Fig. 2-D: Appearance of the hip eighteen months following insertion of the Smith-Petersen nail. Arthritic changes are present with beginning collapse of the head.

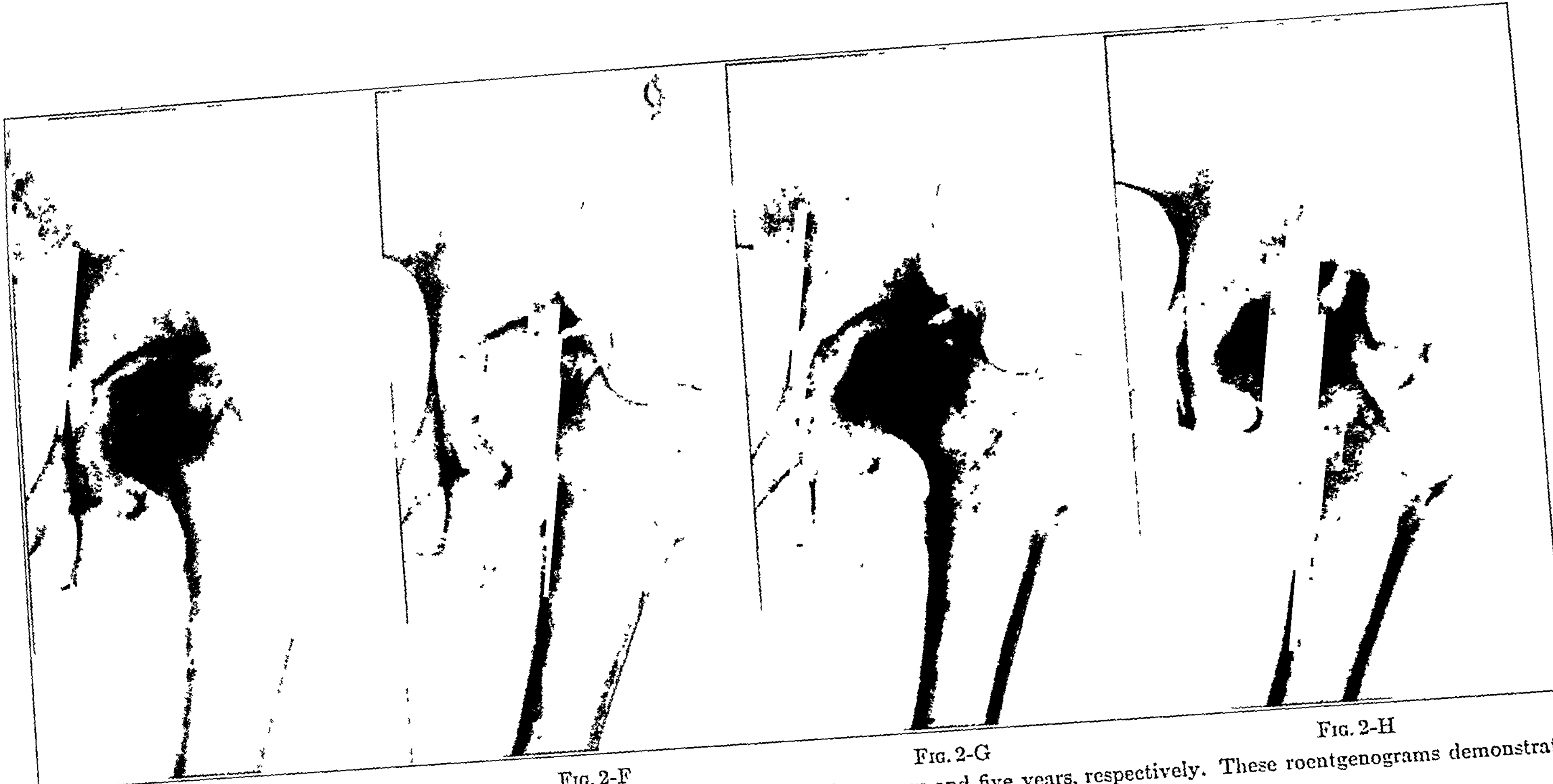

Fig. 2-E

Fig. 2-F

Fig. 2-G

Fig. 2-H

Figs. 2-E, 2-F, 2-G, and 2-H: Appearance of the hip at two years, three years, four years and five years, respectively. These roentgenograms demonstrate a gradually increased collapse of the head, with associated increase in the arthritic changes of the hip joint.

TABLE IV

CHANGES FOLLOWING UNION

Follow-Up Period	No. of Hips	Aseptic Necrosis		Arthritic Changes			
				Moderate		Severe	
		Number	Per Cent.	Number	Per Cent.	Number	Per Cent.
1–2 years	84	28	33.3	13	15 5	6	7.1
Over 2 years	38	13	34 2	10	26 3	12	31 6
Totals	122	41	33 6	23	19 0	18	14.6

TABLE V

END RESULTS

		Per Cent.
Mortality		9.3
Poor End Result		
Non-union	13 5	
Severe arthritic changes	14 6	28.1
Fair End Result		
Moderate arthritic changes		19.0
Good End Result		43 6
Total		100.0

nt of weight-bearing, while those with severe arthritic changes have been definitely icapped because of pain, especially on weight-bearing.

The final results in this series of patients is shown in Table V. According to these findings, the average fracture of the neck of the femur has the following prognosis: mortality, 9.3 per cent.; poor end result, 28.1 per cent., including ununited fractures, and severe arthritic changes; a fair end result, 19 per cent.; and a good end result, 43.6 per cent.

The data presented in this paper indicate that the total number of patients with severe arthritic changes in the hip will exceed the number with non-union. In the future, the problem of rehabilitation and treatment of the patients with severe degenerative arthritic changes may become more important than the treatment of those with ununited fractures.

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NOTE: Discussion of this paper and of the other papers of this Symposium will appear in the April issue of *The Journal*.

Editor

THE PATHOLOGY OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR * †

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That the incidence of non-union is relatively high in intracapsular fractures of the neck of the femur has long been known. More recently, considerable work has been done towards explaining the reasons for this and its prevention. It is now generally agreed that the principal factors which determine whether union or non-union will occur are the extent of original injury, the presence or absence of impaction, the accuracy of reduction and fixation, the survival or death of the femoral head, and the fact that no peripheral callus is laid down because of the absence of a cambium layer on the femoral neck. Although it is well known that union can occur in the presence of aseptic necrosis of the head, still non-union is much more frequent when the head dies than when it survives[11]. It has also become clear that whether or not union occurs, pathological changes in the hip joint are rare if the head is alive, but are constant and may become severe if the femoral head is dead[14]. This paper will attempt a review of the pathological changes seen, following ununited fractures of the femoral neck.

Whether the femoral head survives the fracture depends, of course, on how much the blood supply was damaged; there is no evidence that death occurs long after the fracture when union has failed. There have been several excellent papers which have described in detail the circulation of the femoral neck and head[4,7,9,17]. It is known that the chief supply to the head is through branches of the anterior and posterior circumflex vessels which lie in that portion of the capsule which is reflected up on the neck, and more especially in the posterior portion of the capsule. If this portion remains intact, as it not infrequently does, there may be sufficient circulation to preserve the head. There is also a variable amount of the head which is supplied through the ligamentum teres[4,9,16]. The distribution of these two sets of vessels and the amount of collateral circulation between them vary greatly, but the extent of bone supplied by end arteries may be great. If the neck and capsule are completely severed and the round ligament carries no blood supply, the entire proximal fragment dies.

If the head has remained viable, but non-union nevertheless supervenes, the principal additional change is disuse atrophy which is approximately equal in both fragments. The head never collapses, and it is especially noteworthy that the articular cartilage is well preserved. Operative procedures designed to produce union are usually successful, and degenerative arthritis does not follow. This is illustrated by the following three cases.

CASE 1. M. D., a woman, forty-five years old, whose fracture, treated by skeletal traction and an abduction cast, showed no evidence of union four months later (Fig. 1-A). The roentgenograms revealed the uniform atrophy of both proximal and distal fragments, which is indicative of survival of the head. At operation the entire ununited area was fixed with a tibial peg. A biopsy specimen removed from the head showed living bone. Five months after the operation, healing was well established, and the patient was ambulatory. Two years later, the patient was still asymptomatic, and the roentgenogram showed a cartilage space of normal width and no evidence of degenerative changes in the joint (Fig. 1-B).

CASE 2. F. G., male, aged sixty, was admitted to the Hospital on February 18, 1922, with an ununited intracapsular fracture of the neck of the femur of fifteen months' duration. A roentgenogram (Fig. 2-A) revealed extensive loss of the neck fragments and regional reduction in bone density which was equally marked in the acetabulum, the head, and the distal fragment of the femur. The shadow of the cartilage

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† This work was aided by a grant from the Douglas Smith Foundation.

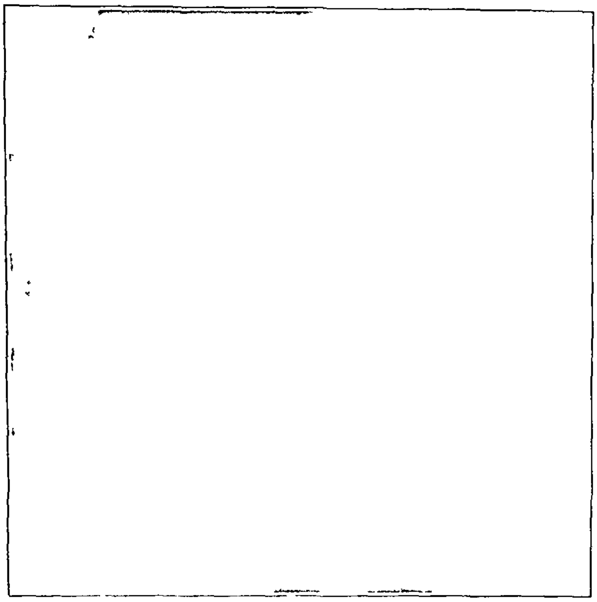

Fig. 1-A

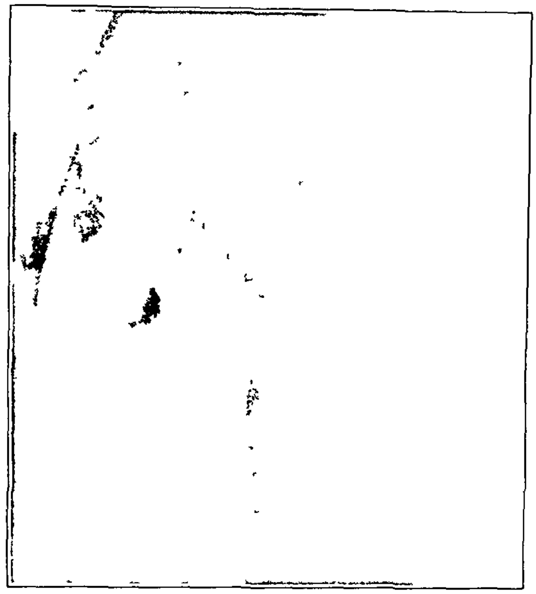

Fig. 1-B

Fig. 1-A: Case 1. Roentgenogram four months after fracture of left femoral neck shows no evidence of healing. Note uniform atrophy of both fragments, indicating a viable head.

Fig. 1-B: Roentgenogram two years after insertion of tibial peg shows union. The head and the rest of the femur are still of the same density, and there is no evidence of degenerative changes in the joint.

space of the joint was of normal width. The uniform reduction of density is indicative of a living atrophic head. A Whitman reconstruction operation resulted in good function (Fig. 2-B).

There was a pseudarthrosis between the two shortened fragments of the femoral neck, which were connected in places by fibrous adhesions. The articular cartilage of the excised head was smooth and normal in external appearance. Only a small part of the proximal fragment of the neck remained, and its eroded fracture surface was covered by fibrous callus bordering on the false joint space. Section of the head showed the articular cartilage to be of normal thickness. There was marked osteoporosis of the bone, which was rich in fatty marrow.

A microscopic section was made of the lower half of the head, extending from the fovea to the fracture line (Fig. 2-C), which disclosed interesting changes: The trabeculae were greatly reduced in size and number, but their cells were alive. The bony cortex, which was covered by an almost normal-appearing articular cartilage, was greatly thinned (Fig. 2-D). The surfaces of the trabeculae were in many places

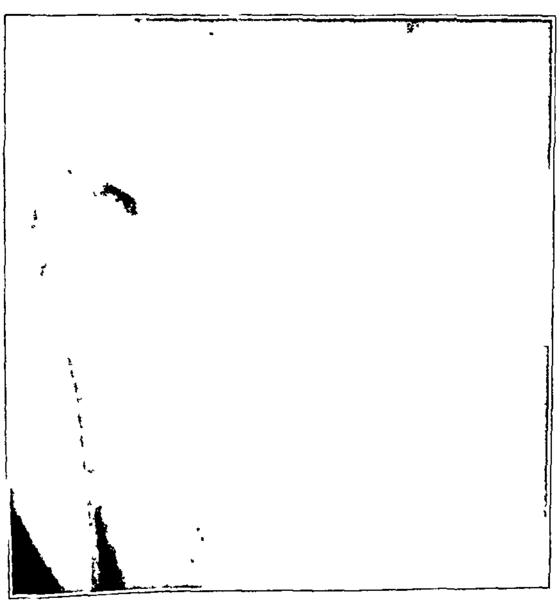

Fig. 2-A

Fig. 2-B

Fig. 2-A: Case 2. Fifteen-month-old ununited fracture of neck. Equal degree of atrophy in both fragments is indicative of a living head.

Fig. 2-B: Three years after Whitman reconstruction operation.

covered by mononuclear cells, some of which were still actively engaged in the process of smooth absorption of bone. The marrow consisted principally of fat, and there was only a small amount of hemopoietic tissue. Near the base of the head there was an island, about one-half centimeter in diameter, of fibrous marrow. New bone had been laid down between the trabeculae along the fracture line to form a cortex which was covered by fibrous tissue with an irregular synovial lining along the surfaces of the false joint. There was no callus along the external surface of the cortex of the neck.

The diagnosis was ununited fracture with pseudarthrosis of the neck of the femur and atrophy of disuse of the viable head.

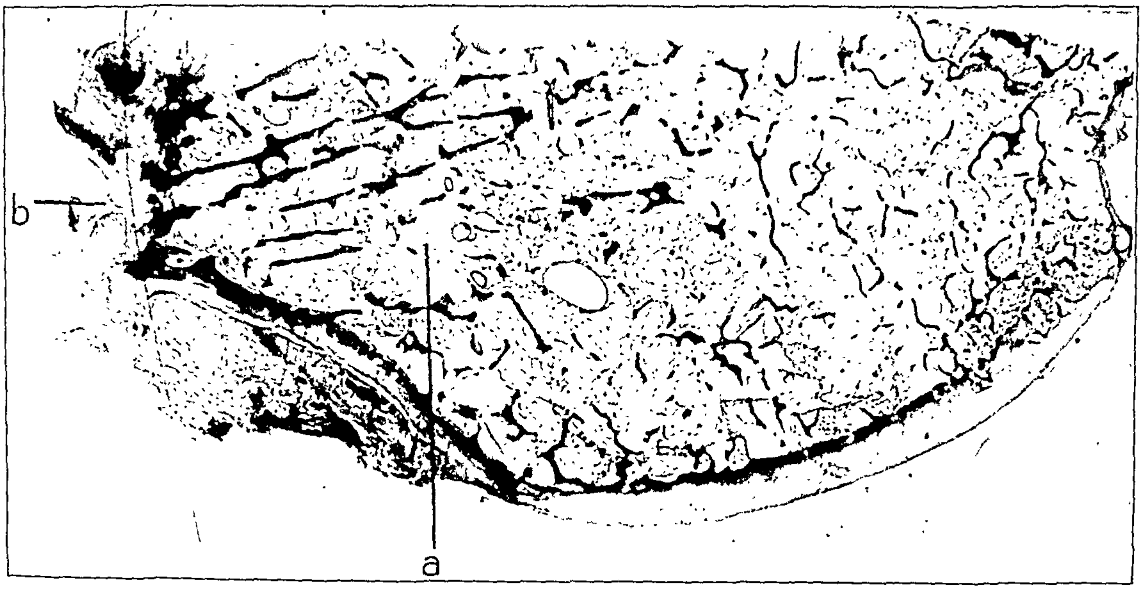

Fig. 2-C

Section through the head from fracture line to fovea, showing atrophic bone with fatty marrow except for fibrous area (*a*) and lining of pseudarthrosis (*b*).

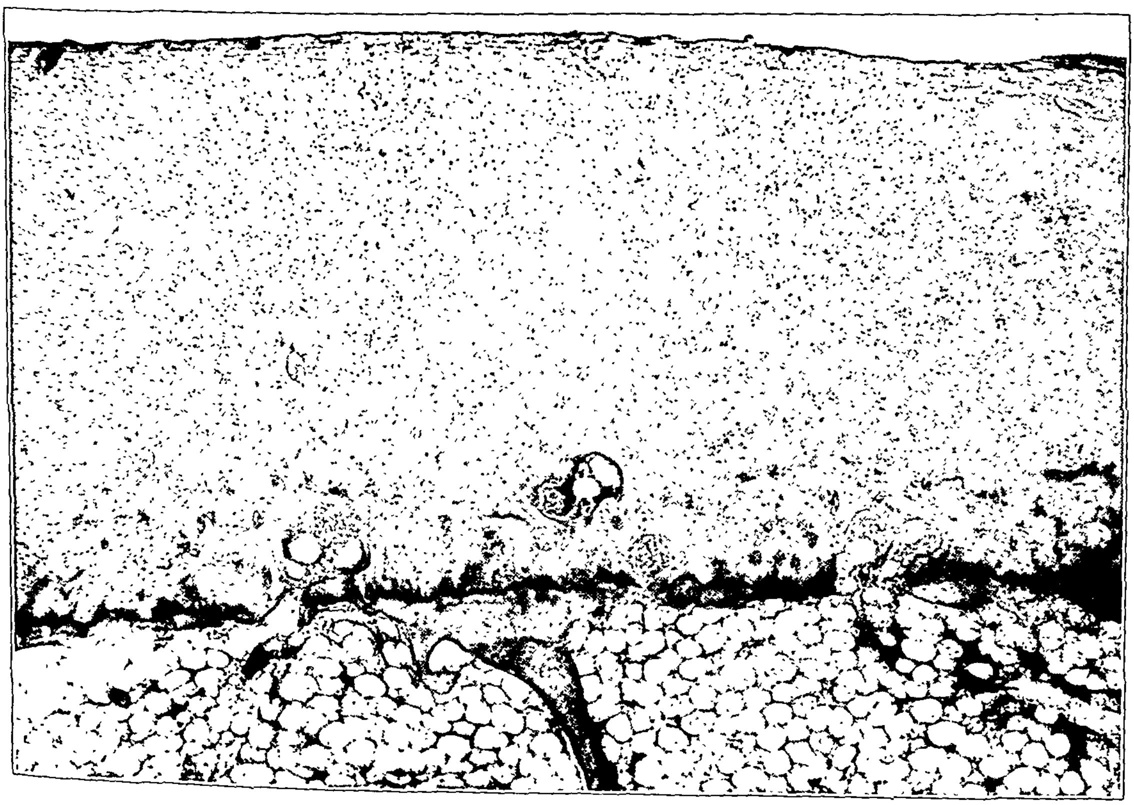

Fig. 2-D

Articular cartilage is changed very little. Bony cortex and trabeculae are greatly reduced in size, but cells are alive. Living fatty and hemopoietic marrow is evident.

CASE 3. A. P., a woman, aged sixty-three years, entered the Hospital with an ununited intracapsular fracture of the neck of the right femur of three and one-half months' standing, which had resulted from slight trauma seven months after x-ray treatments for carcinoma of the cervix uteri. Two roentgenographic examinations during this period showed the hips to be normal.

A roentgenogram at the time of admission (Fig. 3-A) revealed osteoporosis of the bones of the right

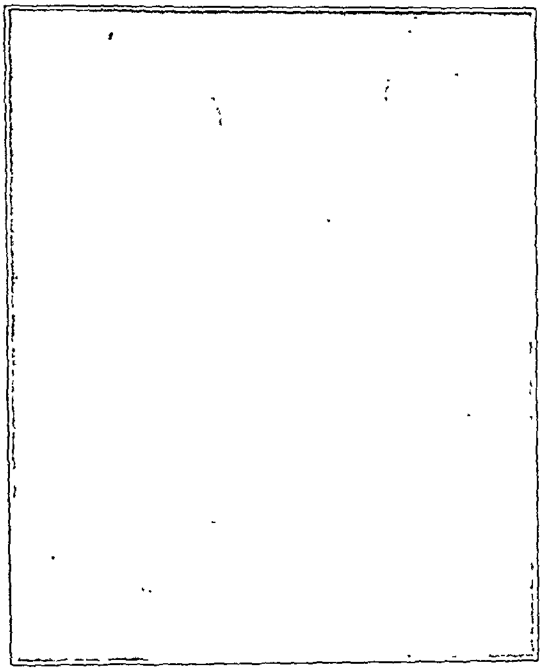

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. An ununited fracture of the neck of the femur, of three and one-half months' duration, which occurred seven months after roentgenotherapy for carcinoma of the uterus. The head is alive.
Fig. 3-B: Two years after operation.

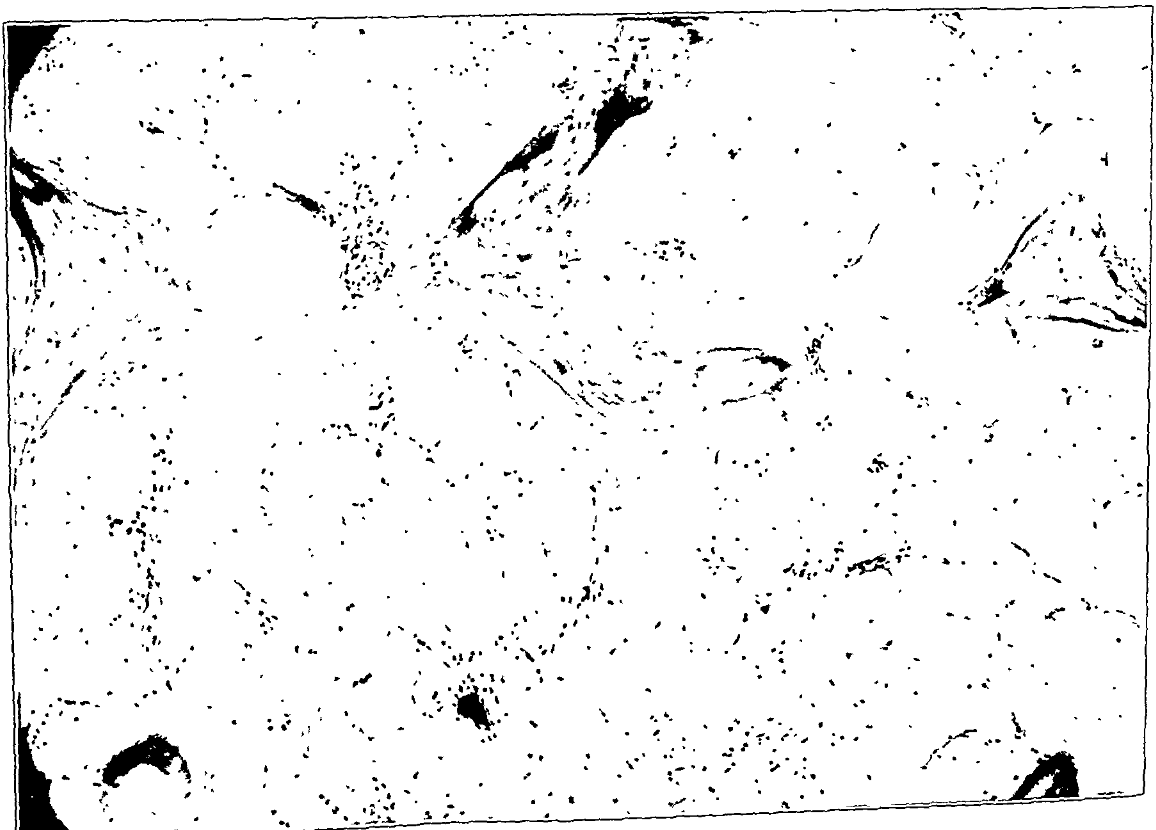

FIG. 3-C
Atrophic living bone of head.

Fig. 3-D

Specimen from edge of neck fragment at fracture margin, showing necrotic trabeculae (*a*), fibrous and bony callus (*b*) of the distal fragment, and trabeculae undergoing creeping replacement by new bone (*c*).

hip region, a subcapital fracture of the neck with upward displacement of the lower fragment, and equality of density of the bone of the two fragments. The opposite hip, which had also been irradiated, showed generalized osteoporosis.

At operation the fracture was reduced and held in position by three heavy threaded wires, and four small grafts of non-irradiated bone were onlaid across the fracture line. Biopsy specimens were taken from the head and from the ends of the neck fragments.

Prompt union followed, and the function of the hip was restored to almost normal. A roentgenogram made two years after operation (Fig. 3-B) showed the density of the pelvis, head, and distal fragments to be about equal and even throughout; the contour of the head and the outlines of the joint space had been preserved, all of which indicates that massive necrosis of the head was not produced either by the irradiation or by the fracture of the neck.

The bone from the head was spongy, and free bleeding occurred during its removal. Microscopically the trabeculae were greatly reduced in size, but the lacunae contained cells, the great majority of which stained normally (Fig. 3-C). The cancellous spaces were filled with fat, throughout which were scattered small islands of hemopoietic cells. The overlying articular cartilage was alive, but showed some fibrocartilage proliferation along the surface at the margin of the head.

Microscopic sections of the specimens removed from the end of the neck fragments revealed a mixture of dead and living trabeculae with fibrous and bony callus in the cancellous spaces and along the fracture surfaces (Fig. 3-D). It is impossible to state how much of the necrosis was due to the radiation and how much to the fracture.

The diagnosis was post-irradiation osteoporosis of the bones of the hip, and ununited fracture of the neck of the femur with survival of the head.

Badgley and Bowman have studied twenty-eight fractures of the neck of the femur, occurring after irradiation for malignancy located in the female genitalia. Of these fractures, eighteen were not treated, seven of which failed to unite. The authors cite the report

of six cases, including three of their own, in which microscopic studies were made of the bone of the femoral neck. There was marked osteoporosis, increase in volume of fatty marrow, and sclerosis of the nutrient vessels. The fibrous callus was avascular, and there was a lack of osteogenesis throughout the fracture area. Minute fragments of dead bone were found in the fibrous tissue. From roentgenographic appearances, it was believed that the head always remained alive[1].

When the fracture disrupts the blood supply to such an extent that the head dies, atrophy of disuse cannot occur. Therefore, as atrophy of the still-living surrounding bone proceeds and the head remains unaltered, it stands out as relatively more dense. Gradually there is invasion of the necrotic portion by blood vessels and connective tissue, which grow in from the edges of the capsule and from the ligamentum teres. This tissue slowly absorbs the old dead trabeculae and at the same time lays down cancellous new bone on other surfaces and in between the trabeculae. This new bone is less dense than the old bone, and thus the roentgenogram of a partially transformed head shows variable density. The necrotic articular cartilage does not show much change until a blood supply reaches it, either from the revascularized underlying bone or from areas such as the fovea. Then it is gradually replaced, either by an imperfect fibrocartilage surface or even in spots by bone. The degenerative changes which follow may be few, if replacement has occurred rapidly and there has been relatively little breakdown. If the reparative process is slow, the articular cartilage wears away, and pieces may break off to form loose bodies. The joint surfaces are badly damaged, and the subsequent osteo-arthritis may be severe.

CASE 4. W. H., a farmer, fifty-seven years old, had been an invalid for three years and bedridden for six months because of amyotrophic lateral sclerosis. A fall resulted in a fracture of the neck of the left femur which, to facilitate nursing care, was fixed with three threaded steel wires. Ten days later, when the fracture was twenty-two days old, the patient expired of pneumonia, and the upper end of the femur was obtained at postmortem examination.

The fracture through the medial portion of the neck was complete, and the two fragments were connected only by the anterior inferior capsule, which remained intact. On section, the bone of the head

FIG. 4-A

Case 4. Roentgenogram of slice of specimen shows greater atrophy of the distal fragment than of the femoral head, which is necrotic.

FIG. 4-B

Microscopic section of specimen shows greater atrophy of the distal fragment. The letters mark the areas from which the photomicrographs were taken.

appeared whitish-yellow, except for a small area around the fovea which was pink. The roentgenogram of the slice cut from both fragments (Fig. 4-A) showed so much old atrophy of disuse throughout that it was difficult to be sure of the nutritional state of the head, but its trabeculae appeared perhaps a little denser than those of the neck and trochanteric regions of the distal fragment. In the large microscopic section, this greater amount of atrophy in the distal fragment was more obvious (Fig. 4-B).

On microscopic examination, the articular cartilage was found to be intact, except along the joint surface where it showed degenerative changes. The lacunae were not seen, the nuclei were shrunken and pyknotic, and the staining was blotchy (Fig. 4-C). The trabeculae of the head were entirely necrotic, except for a small zone around the fovea. In this area the osteocytes were clearly seen, and the normal marrow elements were preserved. In the necrotic portion immediately adjacent to the fovea (Fig. 4-D), creeping replacement of dead marrow and trabeculae had already begun, and new bone was being laid down. Elsewhere there remained no normal marrow, and many of the spaces were filled with amorphous necrotic debris. In places where the vessels remained intact, there was a different picture. The vessels themselves were markedly engorged. The fat cells had survived, and occupying the spaces between them and the swollen vessels there were great numbers of huge pale macrophages, many of which appeared vacuolated or foamy (Fig. 4-E).

The tract of one wire, which was included in the section, was lined with a very vascular fibrous tissue. There was active membranous ossification in this fibrous tissue and rapidly advancing replacement of the dead trabeculae in the walls (Fig. 4-F). The same osteogenic activity was seen in the lower portion of the head, next to the fracture line. The blood supply must have been preserved by, or re-established from, the untorn capsule of this region.

Case 5. R. S., male, aged fifty-seven years, entered the Hospital two days after injury, with an impacted subcapital fracture of the right femoral neck (Fig. 5-A). The limb was immobilized in a plaster spica for two months. A roentgenogram at the end of that time showed healing of the fracture with no apparent density differences between head and distal fragment. The patient walked on crutches until six and one-half months after injury, when a roentgenogram (Fig. 5-B) revealed unaltered density of the head and blotchy shadows of reduced density, proximal to the fracture line in the neck, suggestive of death of the proximal fragment with creeping invasion and replacement by less dense new bone. There was relatively little pain or restriction of motion in the hip. Thereafter, the patient walked with a cane, and one year following injury had only a small amount of weakness and discomfort in the hip. A roentgenogram at that time showed changes similar to those seen in Figure 5-B, and the patient resumed work as a painter. Seventeen months after injury he returned, stating that the hip had recently become more painful.

A roentgenogram (Fig. 5-C) showed a broad zone of blotchy density across the subcapital portion of the neck. There was a slight depression of the cortex of the top of the head where it receives the weight from the acetabulum. The small undepressed area of the head lateral to the superior acetabular margin was irregularly reduced in density, suggesting replacement by new bone. This slight depression of the unaltered weight-bearing portion was indicative of beginning collapse of the untransformed portion of a necrotic head.

The hip steadily grew worse and a roentgenogram nineteen months after injury (Fig. 5-D) showed an irregular fracture line along the base of the head with definite downward slipping of the head and increased density in the neck distal to the new fracture line.

A diagnosis was made of a pathological fracture at the junction of the dead and the transformed living portions of the head and neck.

At operation the head and medial portion of the neck in the region of the old healed fracture were resected, and tibial-bone transplantation for fusion of the hip was carried out.

In both roentgenogram and microscopic section of a mid-sagittal slice of the specimen (Fig. 5-E), the line of the recent pathological fracture was clearly seen. The trabeculae of the head fragment were even in density and appeared unaltered. Microscopically, the structures proximal to the new fracture line consisted of old dead bone and articular cartilage, except below the fovea where both articular cartilage and cortex had been invaded by blood vessels from the round ligament and replaced by cancellous new bone. Distal to the new fracture line, the structure consisted almost entirely of living bone, which had repaired the original fracture that interrupted the blood supply of the proximal fragment and had grown into and replaced the old dead bone, except for portions of the heavier trabeculae that were still in the process of being replaced.

The new fracture line passed through the zone of invasion and replacement of the dead bone by living bone, as shown in the photomicrograph made through its lower one-third (Fig. 5-F). The uninvaded bone of the head (*a*) consisted of trabeculae that were unaltered, except that their cells were gone, and of dead marrow with the outline of the fat cells preserved. The tissue along the invading front (*b*) consisted of connective tissue and blood vessels which had replaced the dead marrow, but had produced little absorption of the dead trabeculae. In the deeper layer, the trabeculae showed evidence of absorption, and in some places, of replacement by spongy new bone. It was in this weakened zone that the

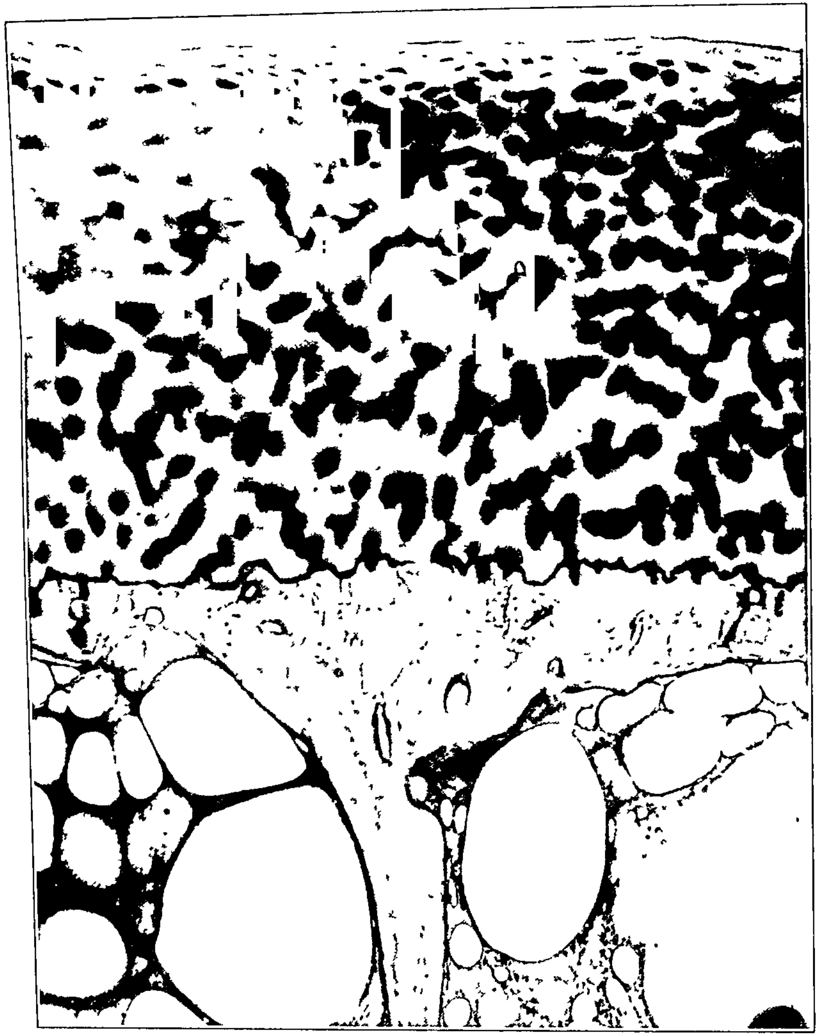

FIG. 4-C

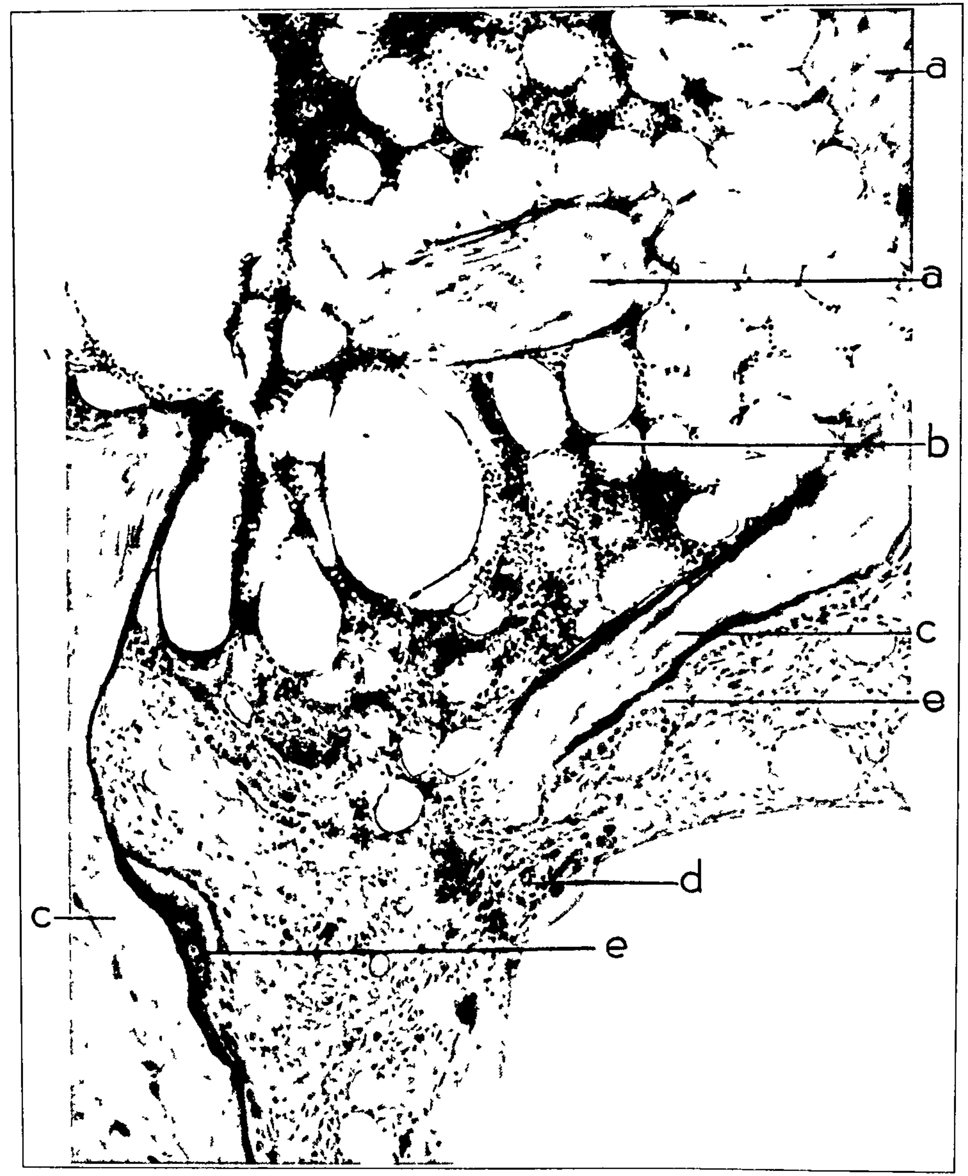

FIG. 4-D

Fig. 4-C: Specimen showing necrotic bone, marrow, and articular cartilage. There has not yet been time for much change to take place in the surface.

Fig. 4-D: Specimen from area of fovea at boundary of living bone and marrow (a, b) and necrotic bone (c), which is already being replaced by new living bone (e). Necrotic marrow is being replaced by vascular fibrous tissue (d).

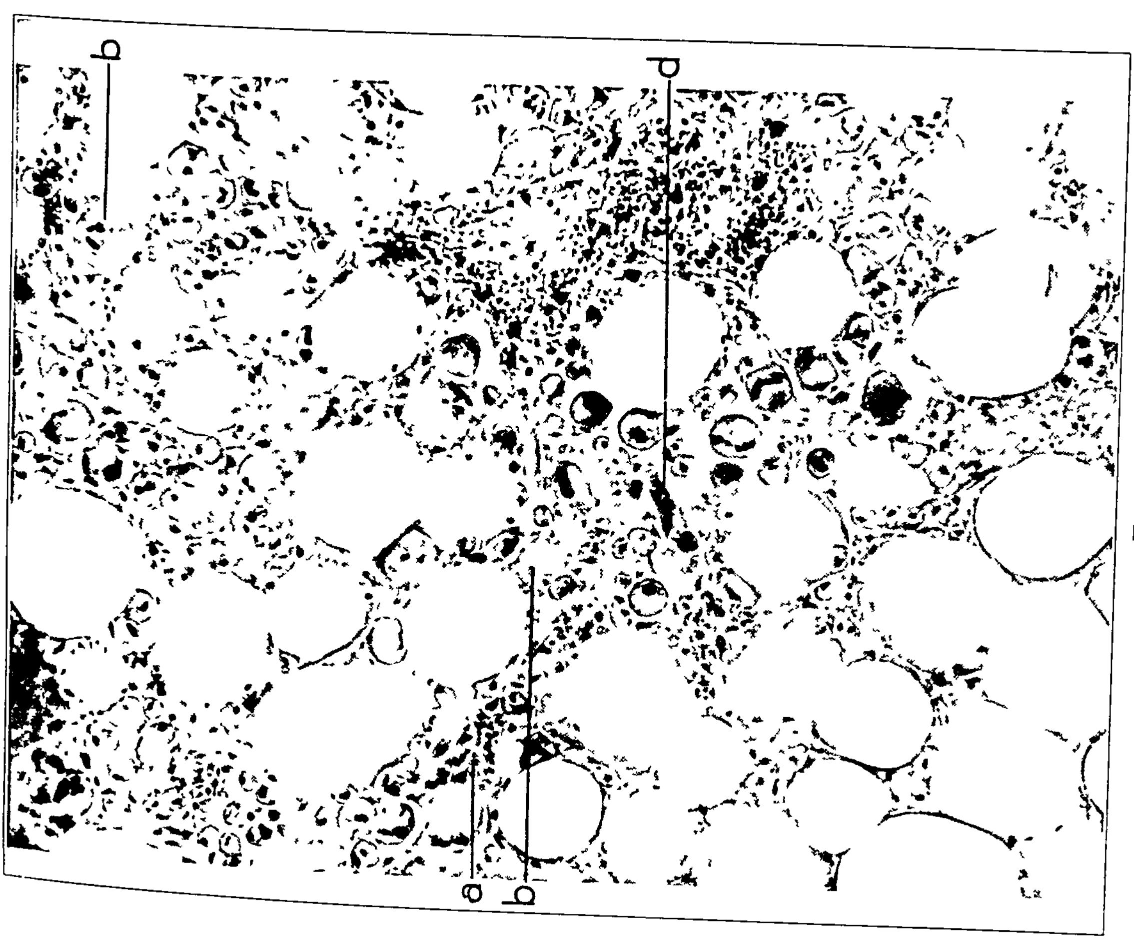

FIG. 4-E

Scattered among the fat cells are engorged blood vessels (*a*) and many swollen, fat-filled macrophages (*b*).

FIG. 4-F

Necrotic trabeculae are covered with a layer of new living bone. In the vascular fibrous marrow there is active membranous ossification.

fracture had occurred. Distal to the fracture, the trabeculae had been largely replaced by living bone, and the marrow consisted of fat, fibrous tissue, and hemopoietic elements. The fracture line was filled with fibrous callus and numerous small fragments of broken trabeculae. There was newly formed bone in some of the callus, and lacunar absorption of the fragments of trabeculae, as seen in Figure 5-G.

Pathological fracture through the junction of the dead and living bone from prolonged weight-bearing is common in aseptic necrosis of the head from any cause[2]. However, it is rare to see almost the entire head sheared off as is the case here. This is because the upper portion is the last to be replaced; and, by the time it has been weakened by invasion, the

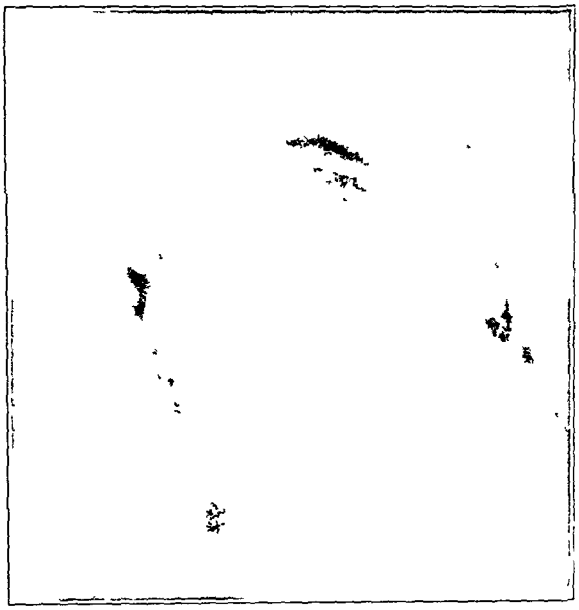

FIG. 5-A

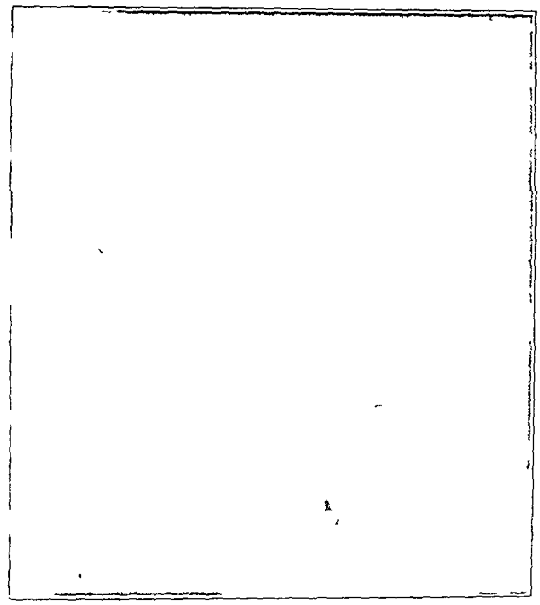

FIG. 5-B

Fig. 5-A: Case 5. Recent impacted subcapital fracture of the neck of the femur.

Fig. 5-B: Six and one-half months after injury. Fracture united. The unchanged density of the head and the blotchy reduction in density of the neck proximal to the fracture site suggest death of the proximal fragment and beginning creeping replacement of dead bone by new bone.

FIG. 5-C

FIG. 5-D

Fig. 5-C: Seventeen months after fracture. Beginning depression of the weight-bearing portion of the head.

Fig. 5-D: Nineteen months after original injury. Recent pathological fracture with downward displacement of the remaining dead portion of the head, produced by weight-bearing on the weak zone of invasion and replacement.

lower portion has already become strong enough to withstand weight-bearing. Therefore, usually only the upper part of the head breaks off and collapses. However, delayed union or non-union between the dead and living portions is the rule[6,11] and in time the collapsed dead bone of the top of the head may even be absorbed and replaced by fibrous tissue instead of bone.

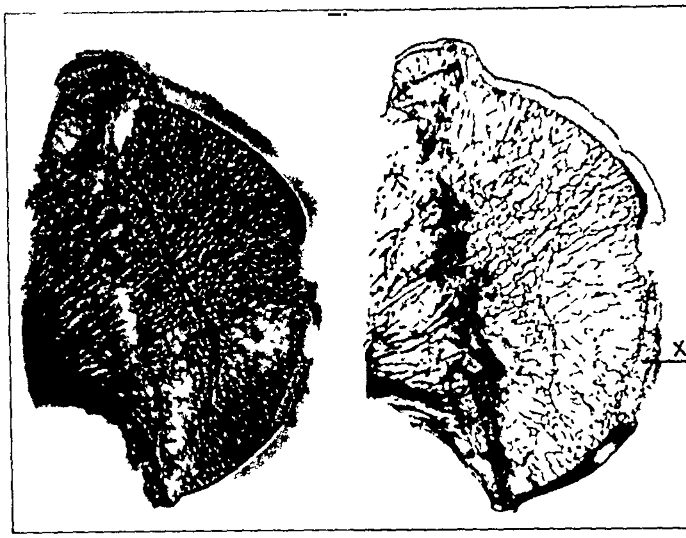

FIG. 5-E

Roentgenogram (left) and stained section (right) of slice of the excised head and part of the neck, showing recent *pathological fracture between distal transformed and proximal necrotic portions.*

CASE 6. W. G., a man of fifty-six, had injured the left hip while bowling two years before his admission. He had enough pain to keep him in bed for ten weeks, at which time a roentgenogram showed a fracture of the left femoral neck. The fracture was reduced and fixed with three Steinmann pins. These were removed seven weeks later, and the patient even returned to work, although he had constant pain and moved with difficulty. A roentgenogram made two and one-half years after injury showed non-union of the fracture (Fig. 6-A). The femoral head appeared denser than the surrounding bone and there were very few areas of decreased density, which indicates little replacement. The necrotic femoral head and two well-developed loose bodies were removed and a hip fusion was performed with a tibial graft. The fusion was clinically solid nine months

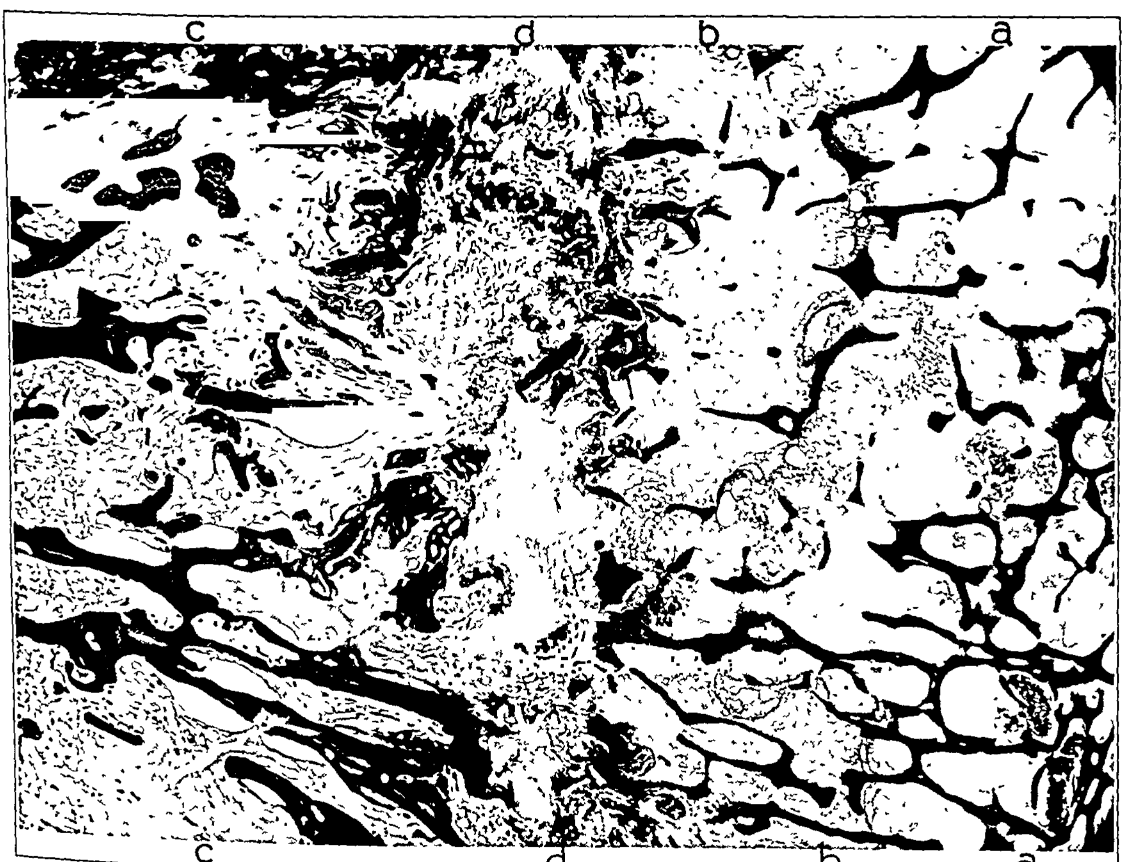

FIG. 5-F

Zone of invasion and replacement of dead bone by living bone, and fracture line through its weakened portion. *a–a* is the uninvaded dead head; *b–b*, the front of the invading tissue; *c–c*, the replaced living bone; and *d–d*, the new fracture line.

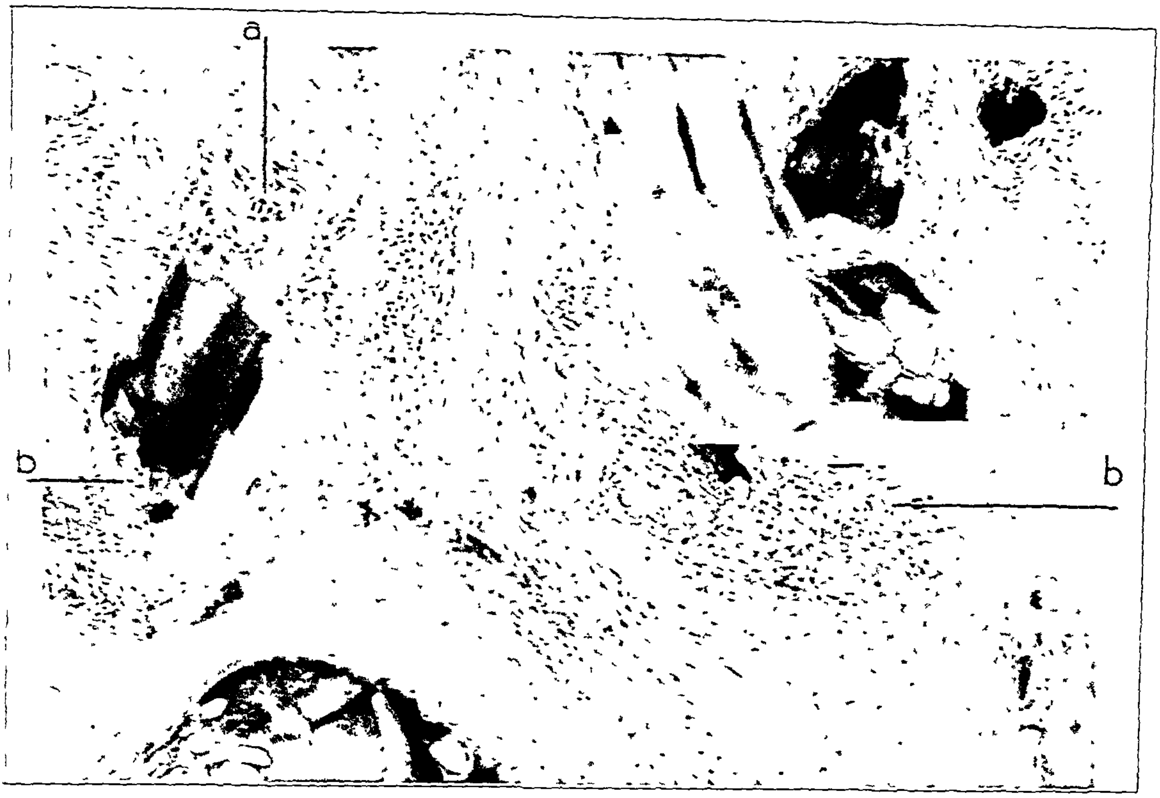

FIG. 5-G

The fracture line (× 150), showing fibrous callus with newly formed bone (*a*) and lacunar absorption of fractured necrotic trabeculae (*b*).

after operation. A photograph of the excised head shows the marked degeneration of the articular surfaces (Fig 6-B).

A roentgenogram of a sagittal slice of the head demonstrates the great difference in density in different areas (Fig. 6-C), and the reason for this is seen clearly in the section (Fig. 6-D). The upper weight-bearing portion of dead bone shows no tendency towards revascularization. The articular cartilage and all the trabeculae are necrotic, and the marrow spaces are filled with an amorphous, pink-staining debris (Fig 6-E). At the upper edge, this debris, in which appear nodules of living fibrocartilage, several of which surround bits of dead bone, has separated the articular cartilage from the bone below. The central portion of the head, which corresponds to the "cystlike" areas seen on the roentgenogram of the slice, exhibits, in addition to necrotic cartilage and trabeculae, marrow spaces which are entirely filled by a dense mature fibrous tissue. This tissue is quite inactive and in most regions there is an absolute *lack of osteoblasts and osteoclasts, showing that repair has come to a standstill (Fig. 6-F).* However, in the region of the fovea and also at the fracture edges, where weight-bearing is not a discouraging factor and where blood vessels are abundant, there is evident osteogenic activity and creeping substitution has begun (Fig. 6-G). Figure 6-H shows a section of one of the osteocartilaginous loose bodies.

CASE 7. J. G., a seventy-year-old man, had been an inmate of the county poor farm for two years *before he died of bronchopneumonia There was no record as to the clinical condition of the right* hip. At postmortem examination an ununited fracture of the right femoral neck was found, and the entire hip joint was removed.

Although there was no evidence of union of the fracture fragments, the head was firmly bound both to the remnants of the neck and to the acetabulum by dense fibrous adhesions. On the cut surface of the sliced specimen *there was noted a large area of bone in the mesial portion of the femoral head* bordering on the superior articular cortex. This bone was white, and its trabeculae were much heavier than those of the surrounding portions, from which it was separated by a narrow strip of pearly-gray fibrous tissue. In the porous bone immediately surrounding this area, there was a brownish zone of marked vascularity. A roentgenogram of the slice showed complete absorption of the neck with marked sclerosis of the surfaces bordering on the ununited fracture line (Fig. 7-A). There was severe degeneration of the joint surfaces, and the roentgenographic changes are indicative of the partial replacement of a necrotic head. Substitution had proceeded up from the fracture line and inferiorly along the capsular attachments, so that a portion of dense bone had been surrounded by bone of reduced density and was clearly outlined. A separate little island of replaced bone could be seen in the region of the old fovea. The same areas can be identified grossly on the *large microscopic section* (Fig. 7-B).

Microscopically these areas were composed of trabeculae which had been almost completely replaced by spongy living bone, except for a few persisting central cores of necrotic bone. Normal fatty marrow was present. Within the dense portion both bone and marrow were completely necrotic, and there was no evidence of replacement (Fig. 7-C). The boundary between living and dead bone was clearly marked by a narrow zone where dense collagenous fibrous tissue filled the marrow spaces, but where there was absolutely no osteogenic activity. In many places, where advancement of the process had apparently come to a halt, there was calcification in the fibrous tissue. Immediately beneath the fibrous tissue was vascular living marrow at the edge of the advancing replacement zone (Fig. 7-D).

The articular cartilage overlying the dead central portion of the head was necrotic, except where a thin layer of fibrocartilage had grown over the surface. Over the foveal area of living bone the cartilage, though imperfect, had been revitalized. From the edges of this island, blood vessels had extended into the adjacent dead tissue and along them calcification and even ossification within the necrotic articular cartilage were taking place (Fig. 7-E). On both sides of the dead portion of the head, where replacement had proceeded right up to the cortex, the articular cartilage appeared to be living (Fig. 7-F).

On the acetabular side of the joint the changes were also spectacular. There was nowhere any normal articular surface. At both edges there was very imperfect fibrocartilage formed over bony spurs which grew over the old surface. Remnants of the original articular cartilage could be seen four or five millimeters back in the bone. There was no trace of the original bony articular cortex. Such marked changes in the articular surface of the acetabulum were commonly seen in old cases of ununited fractures of the femoral neck with death of the head[12,13].

It is noteworthy that degenerative arthritis is regularly present in long-standing cases of necrosis of the head with non-union,

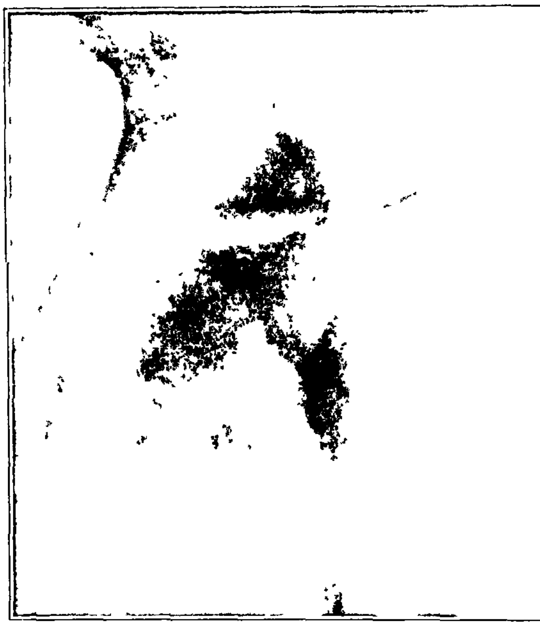

FIG. 6-A

Case 6. Two and one-half years after fracture of the left femoral neck. The head is denser than the rest of the femur. The small area of decreased density at the lower edge indicates replacement.

FIG. 6-B

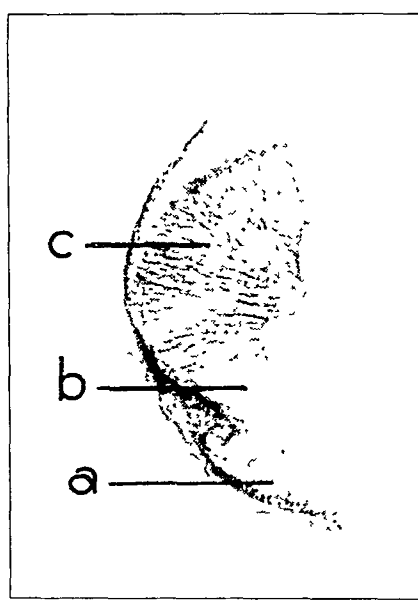

FIG. 6-C

Fig. 6-B: Photograph of the excised femoral head shows marked degeneration of the articular cartilage, which in places has been worn completely away.

Fig. 6-C: Roentgenogram of a slice of the head shows replacing new spongy bone (a ne invaded by fibrous tissue (b), and uninvaded dead bone and marrow covered by nec lar cartilage (c). The separation of the cartilage at the top is an artefact.

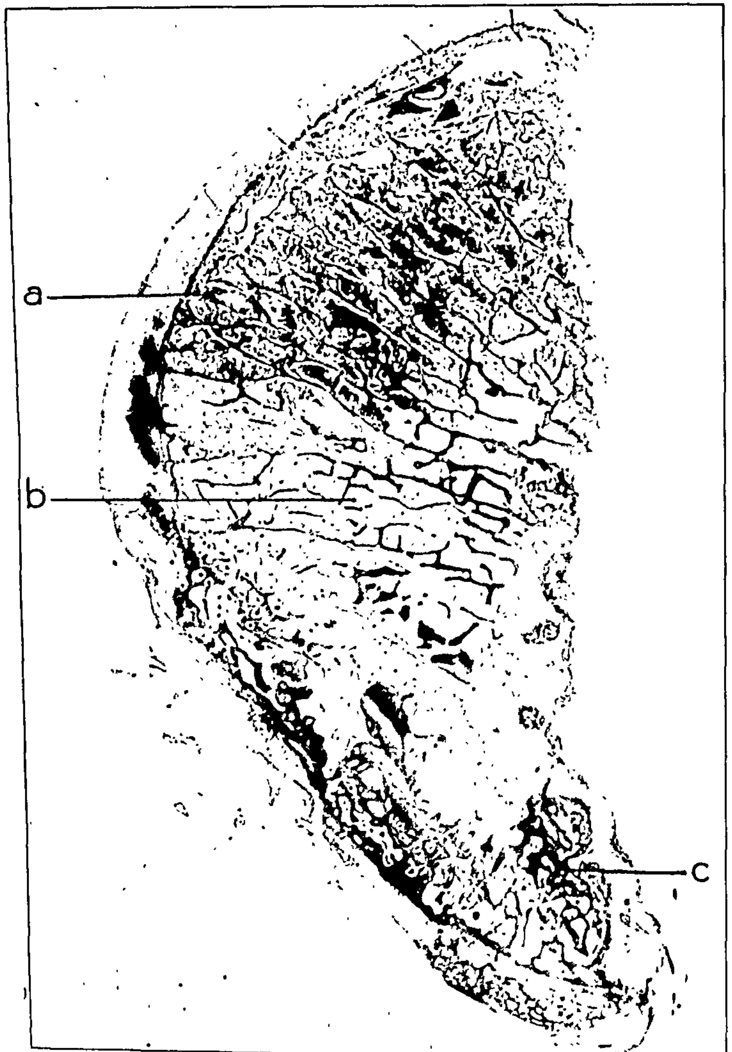

Fig. 6-D

Microscopic section of a sagittal slice of the head. The entire head is necrotic, except for a small area at the bottom which has been replaced by new bone. In the center there is fibrous tissue which is absorbing, but not regenerating, bone. The upper weight-bearing portion has not even been invaded by fibrous tissue. Letters refer to photomicrographs (Figs. 6-E, 6-F, 6-G, and 6-H).

Fig. 6-E

Necrotic bone from upper part of head (*a* in Fig. 6-D) with marrow spaces filled by amorphous debris. Beginning degeneration of dead articular cartilage is evident.

it is rarely as severe as in old cases of necrosis of the head with bony union. When ᵔre is non-union of the fracture, there is usually no collapse of a necrotic head; but, if e fracture unites in the presence of a dead head and weight is borne, collapse of the artially replaced head is to be expected.

The treatment of ununited fracture of the neck with death of the head by open reduction and fixation of the fragments may be followed by bony union. Under favorable circumstances, the head may be invaded and replaced by new bone, and the articular cartilage may be either replaced by fibrocartilage or rejuvenated by early reestablishment of an underlying living bone. In this event, a good functional result is obtained, although it may be followed some years later by degenerative arthritis.

In a previously reported case[12] of non-union of two months' standing with death of the head, bony union followed fixation with a Smith-Petersen nail. The head was gradually invaded and replaced, but not before a small portion of the top had collapsed (Fig. 8-A). Function of the hip returned to normal, except for slight limitation of flexion, and has remained so for thirteen and a half years. A recent roentgenogram (Fig. 8-B) shows almost complete reconstitution of the head. The general density is the same as that of the surrounding bone, except for a few persisting areas of radiolucency in the superolateral

Fig. 6-F

Necrotic trabeculae at center of head, completely surrounded by dense inactive fibrous tissue. There is no sign of new bone being formed.

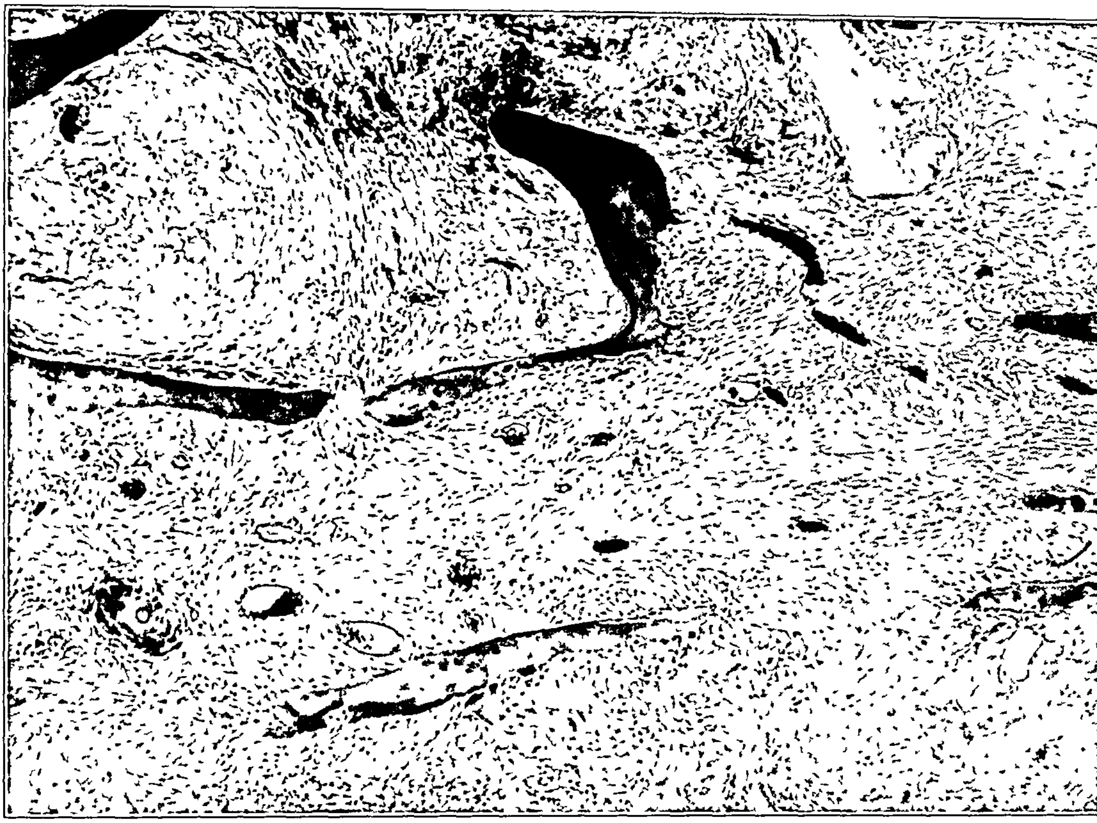

Fig. 6-G
Lower edge of head, showing many osteoclasts absorbing dead bone, while osteoblasts are laying down new bone on other surfaces.

Fig. 6-H
Microscopic section of one of the loose bodies removed from the hip joint.

Fig. 7-A

Case 7. Roentgenogram of a slice of the hip joint shows ununited fracture with sclerosis of the margins, complete absorption of the femoral neck, the dense center of the femoral head surrounded by bone of decreased density, and gross degeneration of the joint surfaces.

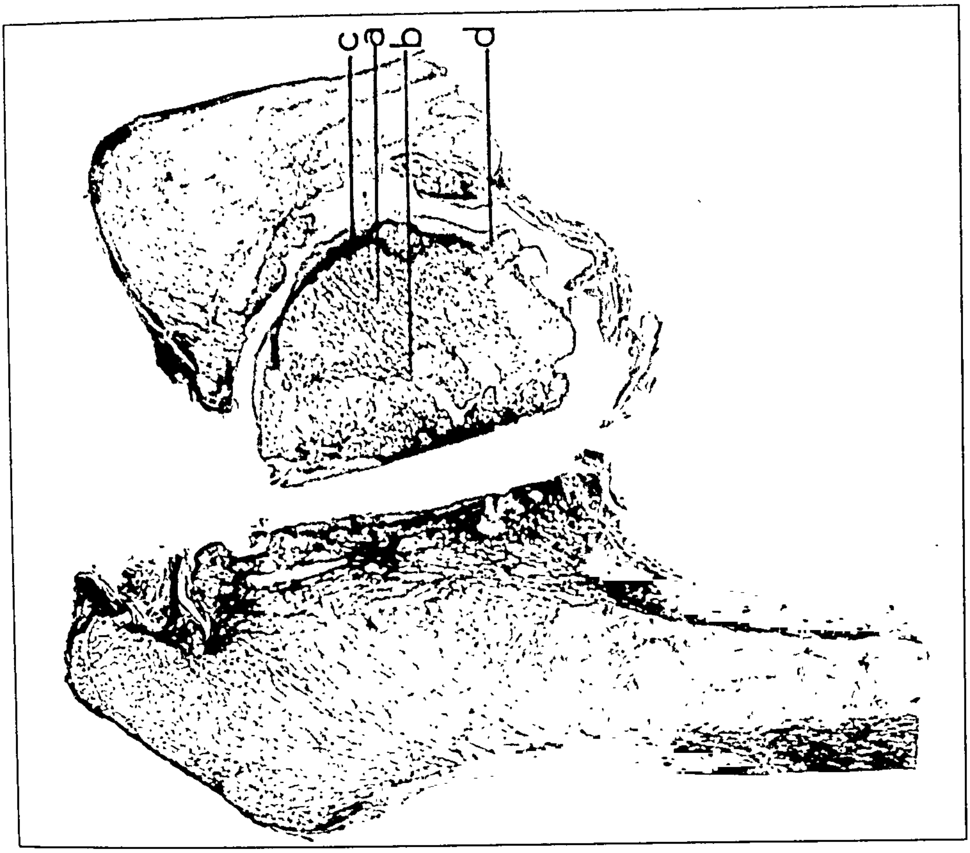

Fig. 7-B

Microscopic section of the hip joint, showing the same changes as Fig. 7-A. Letters refer to photomicrographs.

FIG 7-C

Completely necrotic old bone and marrow in center of dense portion of head

FIG 7-D

Zone of transformation with new vascular living marrow in upper portion In the lower portion is dead bone and inactive fibrous tissue, in which are several areas of calcification (*a*)

portion The contour of the head is slightly irregular and, although the cartilage space is as wide as that of the other hip, there is beginning sclerosis and osteophyte formation on the acetabular side of the hip. Of interest is the presence of marked sclerosis of the opposite sacro-iliac joint.

That a good functional result, lasting for many years, may be obtained in case of a similar fracture of longer standing and in older persons is illustrated by another previously reported case[12], recently restudied.

A woman, fifty-two years old, had an ununited fracture of ten months' standing and a roentgenogram (Fig 9-A) showed normal even density of the upper portion of the head, while the density of the

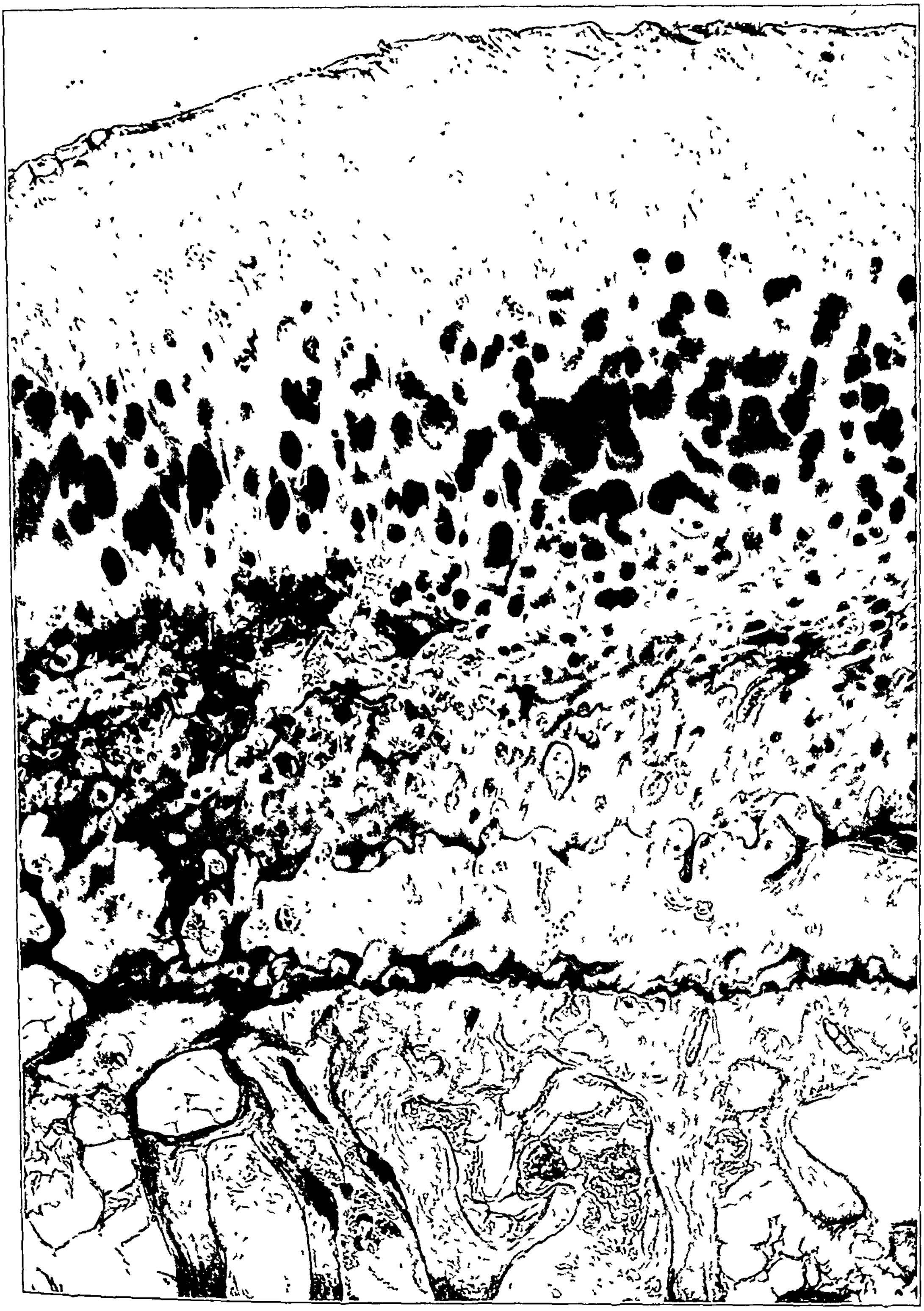

Fig 7-E

Necrotic bone and marrow at surface of dense center of head The old necrotic articular cartilage has been invaded by vessels from the foveal area, and calcification and ossification are taking place along them The surface is overgrown with a new layer of living fibrocartilage

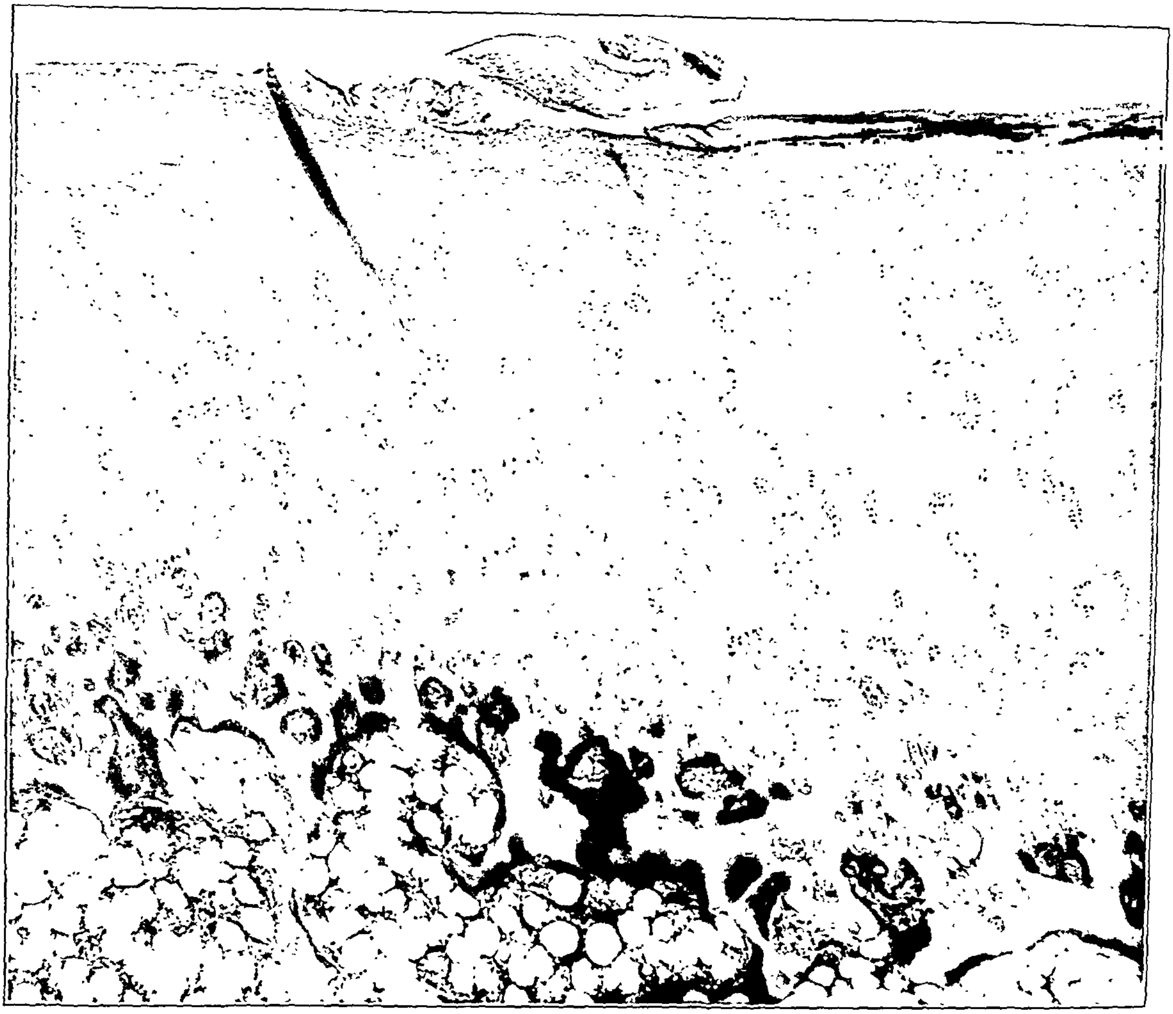

FIG. 7-F
Section from lower margin of head, where replacement is complete, shows living bone and marrow with revitalized articular cartilage.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 8. One year after fixation of a fracture of the femoral neck, with non-union after

Fig. 8-A: *(continued)* two months. There has been partial replacement of the necrotic head with collapse of a small portion of uninvaded bone at the top.

Fig. 8-B: Thirteen and one-half years after operation. There is complete replacement of the head. The joint space is preserved, but the contour of the head is irregular and there is beginning degenerative arthritis.

Fig. 9-A

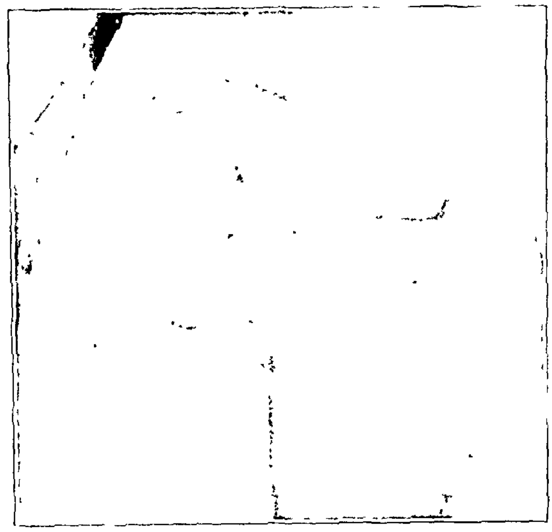

Fig. 9-B

Fig. 9-A: Case 9. Fracture in a woman, fifty-two years old. Roentgenogram taken ten months after fracture, showing death of femoral head with absorption and extensive replacement of its lower portion by new bone of low density.

Fig. 9-B: Ten and one-half months after operation, showing extensive replacement of head.

lower portion was greatly reduced and irregular. This was evidence of death of the head, and absorption and replacement of the lower portion by less dense spongy new bone. The fracture was openly reduced and fixed by two tibial bone grafts and three threaded wires. Healing occurred promptly with excellent return of function which has been maintained up to the present, seven and one-half years later. The wires were removed after eight months. The roentgenograhic appearance is shown ten months afterward (Fig. 9-B), and seven and one-half years afterward (Fig. 9-C). There was a high degree of replacement of the upper portion of the head after ten months, and complete replacement without degenerative arthritis or collapse of the head after seven and one-half years (Fig. 9-C). The drilling of the upper portion of the head for bone-grafting may have hastened the invasion and replacement of the dead bone by new bone. The possibility of impairment of function from the development of degenerative arthritis in the future is not precluded.

Fig. 9-C

Dead bone of head has been completely replaced by new bone; the joint changes are minimal.

SUMMARY AND CONCLUSIONS

1. The incidence of non-union is disproportionately high in intracapsular fractures of the neck of the femur, except in those which are either impacted or treated by accurate reduction and internal fixation. Factors entering into this high incidence are the frequent occurrence of death of the head fragment from disruption of the blood vessels of the neck, displacement of fragment ends, poor immobilization, and failure of peripheral callus formation due to absence of a cambium layer on the neck.

2. If the head fragment survives, it undergoes atrophy of disuse of the same degree as that of the distal fragment, and the two fragments are of equal density on the roent-

genogram. Treatment to produce union is usually successful and extensive degenerative changes in the joint do not occur.

3. If the blood supply to the proximal fragment is severed, so that the head dies, disuse atrophy cannot occur, and the head eventually appears on the roentgenogram to be more dense than the surrounding atrophic, living bone. As slow invasion of the head by vascular fibrous tissue occurs, with absorption of the necrotic bone and replacement by cancellous new bone, the roentgenogram shows areas of reduced density.

4. The necrotic articular cartilage remains relatively unaltered until a blood supply reaches it, when it is replaced either by an imperfect type of fibrocartilage or in part by bone.

5. Transformation of a dead head takes place first at the margins of the fracture and at the fovea, and the advancing replacement zone is the weakest part of the bone. Pathological fracture between the dead and living portions may result in collapse and delayed union or non-union.

6. If union has occurred, either primarily or as the result of surgical intervention in the presence of a dead head, and if weight-bearing is begun before replacement is complete, the head will probably collapse, and degenerative changes will be severe on both sides of the joint. If the head is adequately protected, it may be transformed without any collapse; the degenerative changes in the joint are minimal; and a good functional result is obtained.

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Note: Discussion of this paper and of the other papers of this Symposium will appear in the April issue of *The Journal*. — *Editor.*

COMPLICATIONS OF OLD FRACTURES OF THE NECK OF THE FEMUR RESULTS OF TREATMENT BY VITALLIUM-MOLD ARTHROPLASTY*

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INTRODUCTION

Vitallium-mold arthroplasty has been performed in forty-two cases, presenting complications of femoral-neck fractures, during the past seven and one-half years. This is a small series, and some of the cases reported fall into the class of "early" rather than "end" results. Our statistics, therefore, may change for better or for worse, as the years go by. It is fair to say that the study of results up to the present time is encouraging.

OPERATIVE PROCEDURES

Mold arthroplasty consists in first creating a joint as nearly perfect, mechanically, as possible, and then guiding nature's repair by means of an inert mold, and carefully supervised exercises. As applied to the treatment of complications of fractures of the femoral neck, the procedure is varied, according to the extent of the degenerative changes; four different types of mold arthroplasty have resulted:

1. Routine mold arthroplasty;
2. Modified Whitman reconstruction operation;
3. Modified Colonna reconstruction operation;
4. Intertrochanteric mold arthroplasty.

FIG. 1-A

Case A. F. Moderate aseptic necrosis of the femoral head in a woman, forty-eight years old. She had sustained a subcapital fracture two years previously and had been treated by traction for five weeks, followed by partial weight-bearing on crutches for six months. Full weight-bearing without pain was possible until sixteen months after the accident; at this time onset of pain necessitated return to crutches. Vitallium-mold arthroplasty was performed two years and three months after injury. This was a very favorable case, because the aseptic necrosis was moderate; bone and muscle atrophy was also moderate, due to the absence of complete immobilization and to persistent, even though limited, function.

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1946.

† On Rockefeller Travelling Fellowship.

FIG. 1-B

Two and one-half years after the arthroplasty, the report of the examination read: "Walks without a limp, no pain. One-half inch of shortening. Motions: Hyperextension, 5 degrees; flexion, 115 degrees; internal rotation, 10 to 15 degrees; external rotation, 15 to 20 degrees; abduction, 20 degrees; adduction, 20 degrees." Patient returned to her work as a music teacher in the public schools ten months after the arthroplasty.

This case illustrates the result of a routine mold arthroplasty for limited aseptic necrosis of the femoral head.

FIG. 2-A

FIG. 2-B

Fig. 2-A: A. T. Extensive aseptic necrosis of femoral head and proximal neck in a woman, fifty-seven years old. She had sustained a fracture of the distal neck four and one-half years previously and had been treated by nailing. (This roentgenogram is instructive, because it illustrates the surgeon's habit of outlining the contemplated operative procedure.) In this case the acetabulum was not deepened as planned, because, after removal of the area of necrosis, the neck was found to be too short. Grafts from the iliac crest were introduced into the distal neck and the vitallium mold was applied. The greater trochanter was not transplanted; this was an error in judgment on the part of the surgeon. Six months later the trochanter had to be transplanted, because the reconstructed neck had rotated out of the mold.

Fig. 2-B: Roentgenogram taken eighteen months after arthroplasty, twelve months after transplantation of the greater trochanter. Motions possible at this time: extension, complete; flexion, 90 degrees; abduction, 15 degrees; internal rotation, 15 degrees; external rotation, 10 degrees. There was shortening of five-eighths of an inch. The patient is leading a fairly normal life; swimming and horseback-riding are included in her activities. She uses a cane for outdoor walking.

This case illustrates the result of a modified Whitman arthroplasty for extensive necrosis of the femoral head and proximal neck.

1. *Routine Mold Arthroplasty*

In aseptic necrosis of the head, limited in extent and occurring after union of the fractured neck, a routine mold arthroplasty is indicated. This consists in reshaping the head and acetabulum so as to create two congruous surfaces; the "crater" representing the necrotic area is excised down to bleeding bone and, in cases of relatively extensive necrosis, the resulting defect is packed with cancellous bone from the iliac crest. The reshaped femoral head is covered with a vitallium mold and replaced in the acetabulum (Figs. 1-A and 1-B).

2. *Modified Whitman Reconstruction Operation*

When the aseptic necrosis involves most of the head, even though the fracture has united, a modified Whitman reconstruction is indicated. This consists in discarding the "dead head", reshaping

Fig. 3-A

Fig. 3-B

Fig. 3-C

Fig. 3-A: H. P. Complete absorption of right femoral head and neck with marked atrophy of pelvis and shaft of femur in a woman, fifty-eight years old. She had sustained a fracture of the distal neck four and one-half years previously and had been treated by internal fixation by means of two pins. Non-union had become evident six months later and the pins had been removed. Roentgenogram illustrates a local condition most unfavorable for arthrodesis or osteotomy.

Fig. 3-B: One month after a "modified Colonna". The acetabulum has been deepened medially and posteriorly and its anterior wall excised. The anterior third of the ilium has been osteotomized vertically, and its outer cortex displaced laterally; bone grafts from the iliac crest have been packed into the osteotomy gap. In the abducted position, the trochanter, covered by the mold, is in apposition to the floor of the acetabulum. The superior aspect of the lesser trochanter has been excised to prevent impingement against the inferior acetabulum.

Fig. 3-C: Four years after mold arthroplasty. With the hip in neutral, as far as abduction and adduction are concerned, the trochanter rests against the lateral acetabulum; the osteotomy of the ilium has extended the superior acetabular border, thereby preventing subluxation of the femoral head. There is a wide joint line, indicative of a cartilaginous lining of the acetabulum. Motions possible at this time: extension, complete; flexion, 110 degrees; abduction, 25 degrees; adduction, 30 degrees; internal rotation, 25 degrees; external rotation, 25 degrees. There was shortening of two inches. This patient does all her household duties; climbs stairs normally; uses a cane only for outdoor walking; does not complain of pain.

FIG. 5-A

FIG. 5-B

Fig. 5-A: A. M., a woman, fifty-six years old. Showing a "dead head", absorption of the neck, and advanced atrophy of the greater trochanter. There is also evidence of bone absorption around the nail and the screw. In this case, also, the local condition is unfavorable for osteotomy or arthrodesis.

Fig. 5-B: Roentgenogram taken twenty-seven months after a modified Colonna with osteotomy of the greater trochanter, as described in the text. Report of examination: Walks without a cane with some limp; no limp when walking with a cane. Extension, complete; flexion, 115 degrees; abduction, 25 degrees; adduction, 15 degrees; internal rotation, 35 degrees; external rotation, 35 degrees. Patient does not complain of pain. She returned to her work as a nurse, one year after the arthroplasty.

duced into the acetabulum. The divided muscles are transplanted to the infratrochanteric region and fastened by heavy silk sutures or by wire.

Since the greater trochanter inclines laterally from the axis of the femoral shaft, it has a tendency to be displaced outward from the acetabulum when the extremity is brought into a position of adduction. To prevent subluxation, the anterior inferior ilium is osteotomized vertically, and its outer cortex is sprung laterally; bone grafts from the iliac crest are introduced into the cleft, maintaining the outer cortex in its lateral displacement. By this procedure the acetabulum is deepened by half an inch or so. The lesser trochanter sometimes comes into dangerous proximity to the anterior lip of the cotyloid notch, particularly with the extremity in adduction. Subperiosteal excision of the lesser trochanter, with the distal expansion of the iliopsoas attachment left intact, prevents such mechanical impingement.

4. *Intertrochanteric Mold Arthroplasty*

In one patient, extensive degenerative changes occurred under the mold, allowing the mold to settle down and come to rest on both trochanters. The greater trochanter became so atrophied that it could not be shaped and used for a "modified Colonna". After subperiosteal excision of the lesser trochanter, the intertrochanteric region was reconstructed to fit the mold, and the atrophied greater trochanter was transplanted to the infratrochanteric region of the shaft. The result looks good on paper, as far as mobility is concerned, but the shortening is deplorable (Figs. 4-A, 4-B, and 4-C).

In another case the greater trochanter was similarly affected, but for a different reason. This time the changes were due to extravagant use of the means of internal fixation,—namely, a three-flanged nail accompanied by a screw. In this case the initial arthroplasty was successful and, in the opinion of the authors, it is a better procedure than that just described. The screw had already performed a partial osteotomy, and it was simple to make the osteotomy complete after removal of the screw. The osteotomy performed was similar to a green-stick fracture. The remnant of the atrophied greater trochanter was

then folded downward and medially, and transfixed in this position by means of a small three-flanged nail. As has already been pointed out, the greater trochanter deviates laterally from the axis of the femoral shaft; this procedure, then, has a favorable effect on the trochanter, as regards its stability in the acetabulum (Figs. 5-A and 5-B).

EVALUATION OF THE RESULTS OF THESE OPERATIVE PROCEDURES BASED ON PERSONAL EXAMINATIONS AND INTERVIEWS

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The postoperative results in this series of forty-two cases have been assessed by clinical and roentgenographic examinations, and an effort has been made to determine the value of the operation both to the patient and to the surgeon.

Pain in the hip region is minimal in the majority of the cases, and in both early and late postoperative phases. It is usually present in the form of stiffness on rising from a low chair or at the commencement of activity. *Patients do not complain of low-back symptoms, nor of stiff knees.*

Motion

Mobility of the hip joint has to be considered in conjunction with stability. The greater range of rotation and abduction seen in cases treated by the "modified Colonna" procedure is associated with diminished muscle leverage.

The range of motion achieved by the four operative procedures is shown in Table I.

This motion is invariably smooth and painless, and in no case is there any suggestion of telescoping. It is to be noted that the great majority of these patients have a sufficiently extensive range of hip-joint motion to enable them to dress themselves, including putting on their own shoes and stockings, to sit in comfort in low chairs for protracted periods, and to perform their ordinary household and social activities.

Gait is dependent upon the smooth motion in the hip joint, the stability of the mold in the deepened acetabulum, and muscle power. Strict training and re-education with particular attention to heel-toe movement is most important; and, even in the presence of limb shortening, it is advisable not to raise the heel on the side of the arthroplasty, so that the patient will stretch out the hip and avoid an adductor gait in the early stages. Later, when a good joint is becoming apparent, compensation for shortening is allowable and helps to overcome any Trendelenburg appearance. Unless the gluteal muscles are very weak and the patient is without the support of a cane, a Trendelenburg gait is rarely obvious in these patients, even when climbing stairs.

Residual deformity is more likely to occur, if the operation is complicated by sepsis or failure to maintain the relationship between the mold and the acetabulum. In the majority of the cases, muscle training and exercises prevent any persistent joint deformity, and some degree of shortening alone is present. This is minimal in the patients treated by the routine mold arthroplasty and is more marked after the Colonna and intertrochanteric arthroplasty procedures.

Evaluation of Treatment

The value of this operative treatment to the patient is obvious. Without exception, the younger patients have returned to their work, including such occupations as mining engineer, department-store manager, stenographer, and nurse. The more elderly have been able to perform their social activities, and use a cane for distance walking.

In Table II the functional value of the hip joint, from the point of view of both the patient and the surgeon, is presented; it is to be noted that in two cases the hip is satisfactory to the patient, but not to the surgeon. In three cases, the result is unsatisfactory

TABLE I

RANGE OF MOTION

Hip Function (*Degrees*)	Mold Arthroplasty *20 Cases*	Modified Whitman *5 Cases*	Modified Colonna *14 Cases*	Intertrochanteric Arthroplasty *3 Cases*
Flexion greater than 100	5	–	2	–
between 80 and 100	5	2	3	2
between 60 and 80	7	1	7	–
less than 60	–	2	2	–
Rotation greater than 25	7	1	7	–
between 15 and 25	5	2	4	2
less than 15	5	2	3	–
Abduction-adduction				
greater than 25	6	1	8	2
between 15 and 25	5	3	3	–
less than 15	6	1	3	–
Flexion deformity 10 to 25	1	3	3	–
less than 10	3	–	3	1
External rotation deformity				
10 to 20	–	–	2	–
less than 10	–	1	1	–
Unrecorded	3	–	–	1
Average postoperative shortening	¾ in.	1 in.	1½ in.	2 in.

to both patient and surgeon; and in one case, the patient is dissatisfied, although clinically and roentgenographically the result appears to be good. In the remaining thirty-two cases, both patient and surgeon are satisfied.

Three patients lead a wheel-chair existence due to the following associated illnesses: Parkinson's disease; senility and septic arthritis following nailing; and senility and psychopathic disturbance, with no postoperative rehabilitation for three years.

Complications

Postoperative complications occurred in thirteen patients, five of whom had been operated upon for aseptic necrosis and eight for non-union. They may be grouped as follows:

1. Superficial sepsis with subsequent sinus formation in the iliofemoral scar occurred in two cases. In one case, the infection resolved, but a psychopathic disturbance interfered with postoperative rehabilitation, and the result of the arthroplasty was unsatisfactory. In the second case, revision of the mold arthroplasty and a modified Colonna procedure produced a satisfactory result with resolution of the infection.

2. Deep sepsis was seen in four instances, in two of which the infection originally complicated the nailing operation. One patient died of septicaemia, four months after arthroplasty. In two patients the mold was displaced from the acetabulum; and revision, although unsuccessful in overcoming the subluxation or an occasionally draining sinus,

TABLE II

FOLLOW-UP STUDY

PROGRESSIVE IMPROVEMENT AND ESTIMATION OF VALUE OF OPERATION

Years after Operation	Average Flexion Range (*Degrees*)	Condition of Hip: Satisfactory (*No. of Cases*) To Patient	Satisfactory (*No. of Cases*) To Surgeon	Unsatisfactory (*No. of Cases*) To Patient	Unsatisfactory (*No. of Cases*) To Surgeon
0–2	79	16	17	1	–
2–3	81	3	2	1	2
3–4	85	3	3	1	1
4–5	90	6	5	–	1
Over 5	86	6	5	1	2

enabled satisfactory function to be regained. In the fourth case, septic arthritis had complicated the original nailing operation, and a modified Colonna procedure was done one month after drainage of the joint and removal of the femoral head. Good healing and function were obtained; but, fifteen months later, a blow on the hip resulted in formation of a small sinus, and revision may be necessary if osteitis under the mold and sinus formation persist.

3. Subluxation of the mold upward and laterally occurred in three cases, two of which were treated by the modified Colonna revision and the third by a modified Whitman procedure.

4. Avascular necrosis within the mold was seen in one case, and was apparent clinically by persistent pain and muscle spasm. Revision by intertrochanteric arthroplasty produced a good result.

5. Hypertrophic changes at the mold margin and a flexion-adduction-external-rotation deformity was seen in two cases, one of which was successfully treated by a modified Whitman procedure; in the other case the mold was removed at another hospital, and a subtrochanteric fracture, incurred during the operation, was used as an osteotomy. A satisfactory result is reported, but is not included in this series.

6. Upward displacement of the greater trochanter, in spite of fixation to the femoral shaft by a three-flanged nail, occurred in one case. Weak abductor muscles resulted, but the patient walked well with a cane.

7. Pulmonary embolism did not occur in this series of cases, and prophylactic femoral-vein ligation was used in only one case.

Mortality

There was no operative mortality. One patient died from septicaemia, the source of which was septic arthritis of the hip following arthroplasty four months previously; and two other patients died of carcinoma of the stomach and coronary occlusion, respectively, two and one-half and one and one-quarter years after operation. It is to be noted that half of the patients in this series of cases were sixty years of age or more.

SUMMARY AND CONCLUSIONS

The results of treatment of complications of fractures of the neck of the femur by vitallium-mold arthroplasty have been studied in forty-two cases. Five cases have been chosen as instructive and illustrating the various operative procedures employed.

Based upon this study the following conclusions have been drawn:

1. Eighty-five per cent. of the results are satisfactory to both patient and surgeon.

2. There is progressive improvement in function for three to four years after operation. The condition then becomes stationary. (The postoperative period in the oldest case is now seven and one-half years.)

3. In this series of patients, low-back symptoms, stiff knees, or postural difficulties were not present.

NOTE: Discussion of this paper and of the other papers of this Symposium will appear in the April issue of *The Journal*.

Editor

PAINFUL, NON-SUPPURATIVE, LOCALIZED SCLEROSIS OF THE LONG BONES

WITH A REPORT OF TWO CASES

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Sclerosing non-suppurative osteomyelitis was described by Garrè in 1891, before the roentgen ray was available. Jaffe and Lichtenstein point out that the translated title of Garrè's original paper is "Some Unusual Expressions of Acute Infectious Osteomyelitis", and that one form of these "expressions" is sclerosing non-suppurative osteomyelitis, which was described as setting in acutely with pyrexia, local pain, and swelling. The temperature and soft-tissue swelling subsided; osseous enlargement persisted. This condition has received roentgenographic recognition, and is thus described by Gray:

> "*Sclerosing Osteomyelitis* (Garrè): This is a rare form of chronic non-suppurative osteomyelitis, generally affecting either the tibia or femur in older children and young adults. It is characterised by a diffuse area of sclerosis near the end of the diaphysis, gradually fading off into normal bone.
>
> "The cortex is increased in extent and density, and the medullary cavity may be so much encroached upon as to be unrecognisable. A somewhat fusiform expansion of the shaft results, and there is generally slight roughening of the surface. The X-ray appearances in the early stages of some forms of *Ewing's* tumour may be indistinguishable from this condition."

Some French writers describe cases of osteomyelitis which are "chronic from the beginning" (*chronique d'emblée*). Laffaille records two such cases *à forme pseudo-tumorale.*

Fosdick Jones recorded the case of a boy whose tibia was affected. In June 1918, the patient sustained an injury to the shin, which left no residual discomfort. In December 1918, he sustained another injury at the same site; pain and pyrexia immediately followed and persisted. The boy lost weight and strength. When seen in July 1919, he was thin and anaemic; his temperature was 101 degrees; and the tibia showed a well-marked forward bulge. At operation no pus was found, and cultures from the medullary canal were sterile. Microscopically, there were no foci of round-cell infiltration. Fosdick Jones discussed the differential diagnosis from syphilitic periostitis, sarcoma, and "the rare type of solid osteitis fibrosa encountered in the long bones". He considered this type of bone sclerosis to be rare; and, in the discussion which followed the presentation of this case, Ryerson stated that he had never seen a case which could be classified as Garrè's osteomyelitis. On that occasion Sir Robert Jones instanced a case in which there had been recurrence eighteen months after operation. On the authority of Mauclaire, Fosdick Jones quoted Kocher's opinion that a considerable number of bone enlargements, diagnosed as sarcoma and treated with apparent success by amputation, were merely instances of sclerosing non-suppurative osteomyelitis of the long bones.

In 1920 Bloodgood, under the heading of Pyogenic Ossifying Periostitis, discussed a case previously diagnosed as sarcoma of the femur. The patient had refused amputation. Bloodgood commented that: "A case of this kind demonstrates that some of the so-called cures of periosteal sarcoma after amputation, serum, x-ray or radium belong to this type of periosteal lesion". Bloodgood subsequently recognized a resemblance between this case of femoral ossifying periostitis and the case of tibial osteosclerosis described in the communication of Fosdick Jones, in view of which he concluded that his case also corresponded to the non-suppurative osteomyelitis of Garrè. He further stated: "That I have observed seven cases of this type since February, 1921, a period of thirteen months, is an indication that it is a bone lesion which we must bear in mind". Bloodgood attached the name of infectious ossifying periostitis to this condition, and attributed it to metastasis from some focus of infection.

In reviewing a series of thirty cases of Garrè's osteitis seen at the Mayo Clinic, Henderson stated that seventeen patients were operated upon; of these, nine obtained relief;

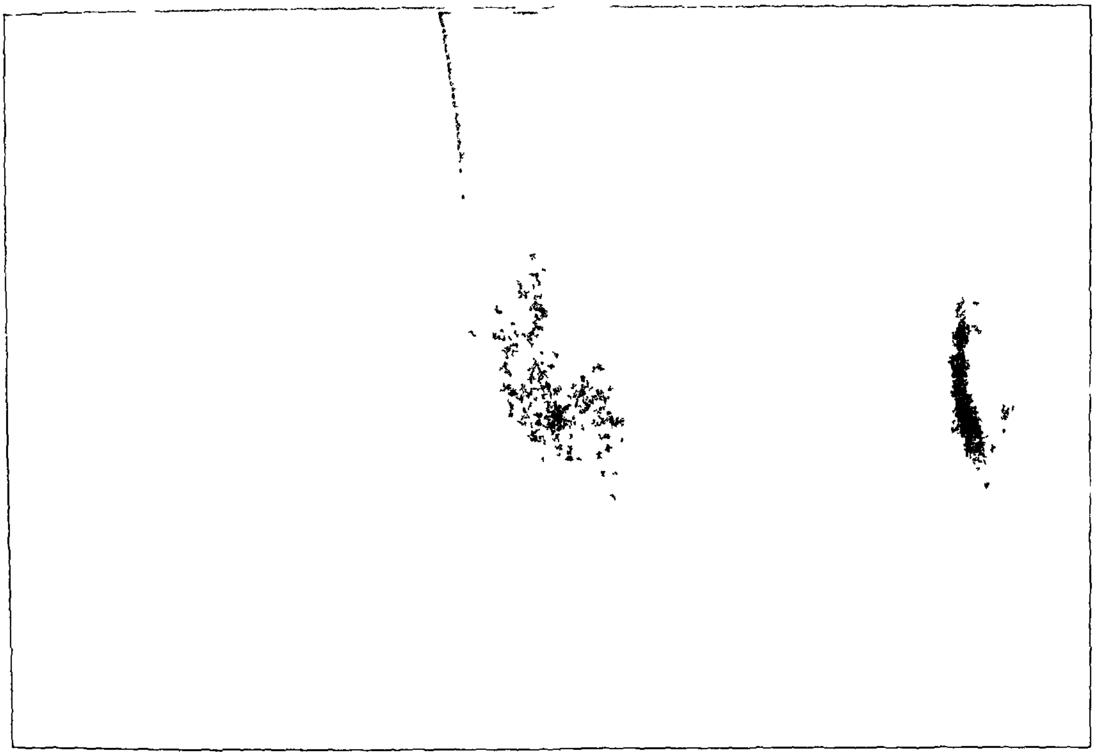

Fig. 1-B
May 1938. Three roentgenograms of varying densities. Illustrations on the right and the left, respectively, indicate the less dense central area.

one was not relieved; two had temporary relief; and five were not traced. Thirteen were not operated upon. Of these, three were relieved permanently; one was relieved but had recurrence; and nine were not traced. The surgical procedure adopted was either "guttering" the bone or drilling multiple holes through both cortices. Out of the thirty cases, he states: "In eight, either previous or subsequent to our examination, there was suppuration, but in only one case a history of necrosis of bone". Henderson states that, although onset may be acute and sudden, more often it is subacute and chronic. There may be atrophy of the limb. Tenderness is usually complained of on deep pressure. "The course of the disease is chronic and long. Recurrences, even after relief has been afforded by operation, are not infrequent . . ." In Henderson's series, different types would seem to have been included.

The silent foci of localized osteomyelitis, which are described by Phemister and which are delayed sequelae of acute osteomyelitis, are essentially different, both roentgenographically and clinically, from sclerosing non-suppurative osteomyelitis.

Wishner described five cases of chronic sclerosing osteomyelitis. In his cases, the evidence for chronic bone infection was relatively slight. In a brief review of this subject, Ewing says: "It may well be that the term osteomyelitis is a misnomer . . . While some believe it is due to infectious organisms in the haversian

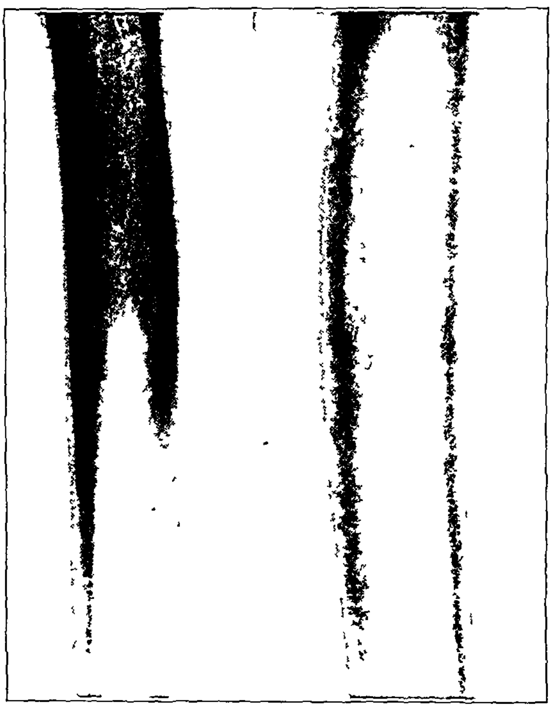

Fig. 1-C
April 1941. Anteroposterior and lateral views of left femoral shaft show disappearance of fusiform enlargement.

spaces which are so attenuated in character as to cause this unusual syndrome, it is more likely that the pathology is due to a diminution in the blood supply locally from some non-infectious irritant, *viz.* trauma."

In 1935, Jaffe described five cases of what he regarded as a benign neoplasm arising within the medulla in spongy bone areas. To this growth he gave the name of "osteoid-osteoma". In 1940 he and Lichtenstein described a further series of such cases, of which thirteen involved the shaft cortex of long bones. The patients were adolescents or young adults. The principal complaint was pain, and "it was this that consistently led the patients to seek medical attention . . . In no case was there a history of febrile episodes in connection with the lesion." Local heat and redness were absent.

Jaffe and Lichtenstein drew attention to two features in roentgenographic appearance of these lesions:

1. The focus (osteoid osteoma proper) is generally indicated by an oval, relatively "clear" area.

2. The surrounding osseous reaction incited in the adjacent bone, when long-bone cortex is involved, results in very marked cortical thickening, which "may extend for several inches both above and below the osteoid-osteoma proper" and may partially envelop the shaft of the bone.

These authors state: "It seems very clear to us that a great many cases which, in the past, have been interpreted specifically as 'osteomyelitis with annular sequestrum', 'chronic bone abscess', 'osteomyelitis with cortical-bone abscess', 'sclerosing non-suppurative osteomyelitis', 'osteomyelitis chronic from the beginning', etc., actually belong in the category of osteoid-osteoma." In their cases, surgical treatment resulted in clinical cure "with prompt and often dramatic relief of distressing pain"; there were no recurrences in seven years.

The clinical and roentgenographic interpretation of this type of bone lesion, put forward by Jaffe and Lichtenstein, has been supported by Harmon, Kleinberg, Lewis, Horwitz, and Stauffer.

Brailsford describes three cases of cortical thickening of the tibia, in which evidence of an inflammatory origin was found on exploration of the bone. (In two cases a "bead of pus" was discovered, and in one of these recurrence took place after operation; in the third case a small cavity suggesting a chronic bone abscess was found, and in this case healing was very slow.) One of his roentgenograms shows persisting tibial enlargement, four years after surgical intervention. With regard to differentiation and acceptance of the bone lesion designated as osteoid osteoma, Brailsford says: "Though the histological appearances as illustrated and described by Jaffe and Lichtenstein lend support to their suggestion that it is a benign tumour of bone, there is nothing in the radiographic appearance which supports this diagnosis."

The presence of visible pus or septic cavitation—even though minute—is not characteristic of the osseous lesion known as Garrè's osteitis. It would appear, therefore, that non-suppurative sclerosis of the cortical bone, accompanied by pain, is a clinical and pathological entity *sui generis*, for the explanation of which the associated existence of a benign neoplasm, designated "osteoid-osteoma", has been postulated by Jaffe and Lichtenstein, who further claim that the lesion admits of roentgenographic verification.

A completely satisfactory interpretation of the total lesion is, however, not provided by the conception of reactive osteosclerosis in relation to a neoplastic center, such as is described by Jaffe and Lichtenstein; these authors, indeed, admit that "why an osteoid-osteoma should arouse a perifocal osteosclerosis is by no means clear".

CASE REPORTS

These cases were characterized by gradual onset and by gradual increase of pain, without an acute phase of illness.

CASE 1. A girl, ten years and ten months of age, who had previously been healthy and without history of injury, was first seen on February 25, 1938. She complained of pain in the left knee and leg, which had begun about three months before; recently it had been severe at night, interfering with sleep.

On physical examination, the child walked with a slight limp (this was said to have been present intermittently for about six months). The femoral shaft was palpably enlarged, and there was tenderness at the level of the center of the enlargement. There was slight wasting, but no apparent affection of the soft tissues or skin; there was no pyrexia; movements were unrestricted.

On roentgenographic examination (Fig. 1-A) the medial aspect of the left femoral shaft showed a dense enlargement, which, at the mid-point, partly obscured the medulla; from that level the thickening gradually diminished, both upward and downward. The cortical thickening extended as high as the lesser trochanter, but did not reach the medial condyle of the femur. In the lateral view, the femoral shaft showed a dense fusiform enlargement; the anterior aspect had a rough "knobby" contour and the posterior aspect had a smooth "layered" appearance.

On blood examination, the leukocyte count was 9550, with 58 per cent. polymorphonuclear cells. A negative Wassermann was found; after "provocative" injections of arsenicals, repeated Wassermann tests were negative. Potassium iodide was administered without effect. There was some oscillation of temperature during this observation period, but later this ceased. Aching in the limb persisted. Further roentgenographic examination, with variation of technique, disclosed what appeared to be a long oval cavity within the thickened and sclerosed bone; the presence of a small sequestrum was faintly suggested (Fig. 1-B).

On June 11, 1938, the bone enlargement was explored and was deeply guttered. Neither pus, nor cavity, nor evidence of sequestrum formation was found. Bacteriological examination of the bone fragments was negative. Histological examination showed dense laminated bone, separated by a cellular connective tissue without inflammatory cell infiltration.

The operative wound healed without inflammatory reaction. Pain in the limb ceased about forty-eight hours after surgical intervention. Tenderness was absent a month later. The child was kept in the hospital until the femoral enlargement was evidently subsiding. When discharged from the hospital on March 11, 1939, she could walk and run well. There has been no recurrence of pain or disability. Roentgenograms of the left femur were taken in 1941; the fusiform enlargement had disappeared, and a barely recognizable trace of the guttering of the bone remained (Fig. 1-C). The left femoral shaft was more massive than the right and showed a slight curvation medialward.

In 1940, the author saw Campbell's roentgenograms of Garrè's osteomyelitis, read his comment on the condition, and noted in particular the negative results of bacteriological examination of this bone lesion. The monograph of Jaffe and Lichtenstein on osteoid osteoma also came to notice, and as a result the symptoms, the roentgenographic picture with cortical thickening and a radiolucent area, and the other findings in Case 1 were recalled.

In May 1945, the following case was seen.

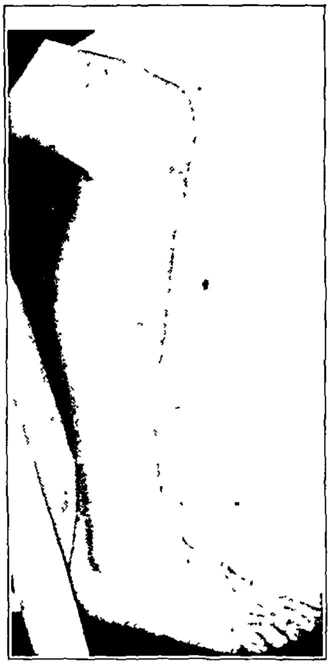

FIG. 2-A

Case 2. Visible tibial swelling. Area of maximum tenderness is marked on skin; this site was shown roentgenographically to correspond approximately with that of the tibial focus.

CASE 2. The patient was a boy of fourteen years who, for about two months, had been complaining of aching in the shin. This discomfort was associated with a sensitive "lump" which the boy attributed to a contusion sustained two months before the onset of the pain (although he was uncertain which shin had been injured).

On examination, a forward bulge of the shin border was evident; there was no redness of the skin nor any swelling of the soft tissues. Later there was slight firm thickening without "pittable" oedema. Tenderness, which was acute, was limited to a small area (Fig. 2-A). The pain and the tibial enlargement gradually increased. Roentgenographic examination in July 1945 (Figs. 2-B and 2-B′) was considered to justify no more than a diagnosis of chronic osteitis. In September 1945, another roentgenographic examination was made (Figs. 2-C and 2-C′). At that time the cortical sclerosis had increased; in the lateral view a radiolucent area was observed. The roentgenologist (Dr. Donald Ramage) expressed his opinion that the diagnosis of osteoid osteoma was now established. Attention is drawn to a special feature of the "clear" area in the roentgenogram,—namely, that it is not sharply outlined (so also in the previous case).

Pain persisted, increased, and interfered with sleep; assent to surgical treatment was given.

The leukocyte count was 6200, with 53 per cent. polymorphonuclear

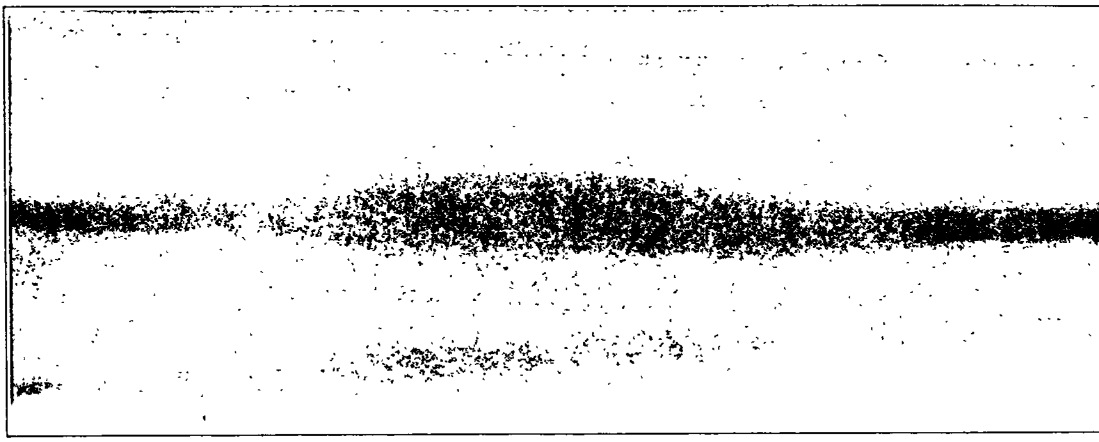

Fig. 2-E
February 28, 1946

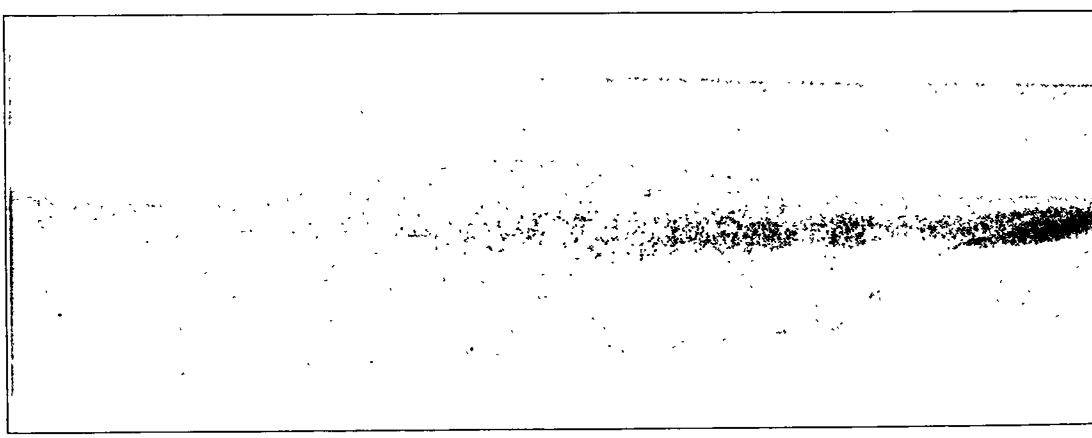

Fig. 2-D
January 23, 1946

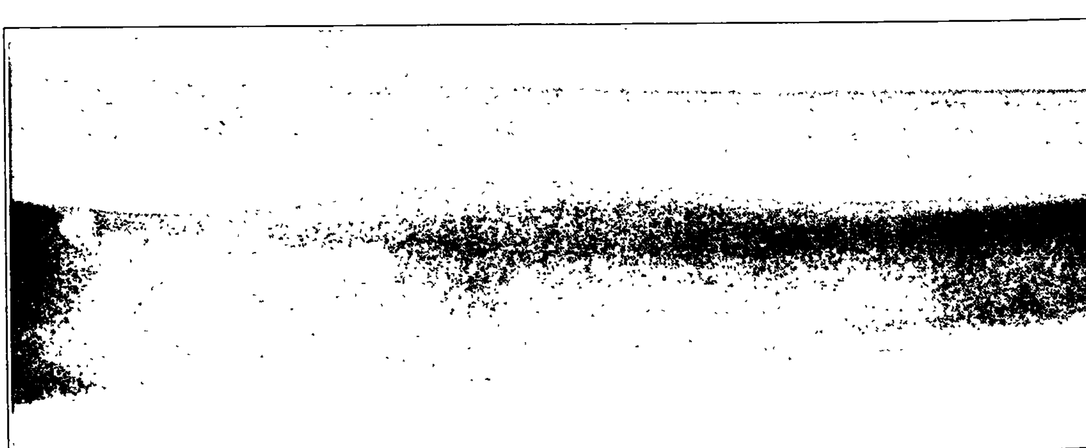

Fig. 2-C
September 26, 1945

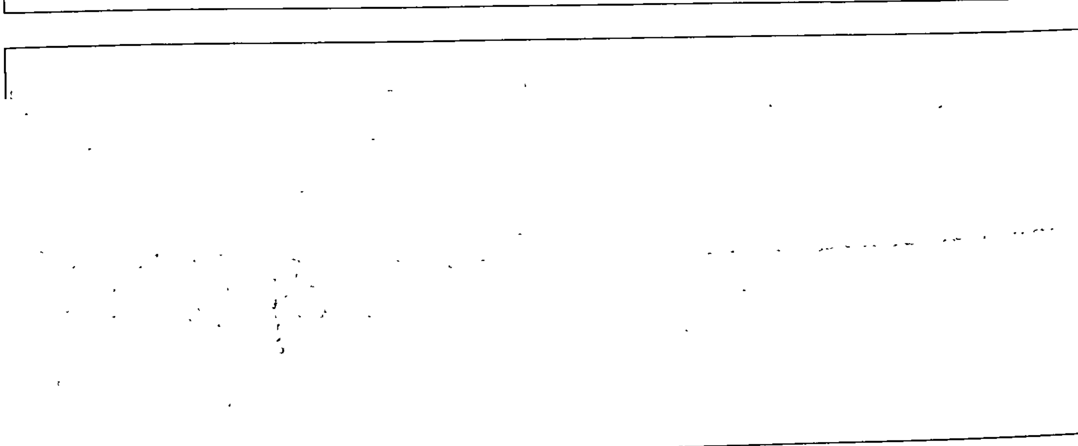

Fig. 2-B
July 9, 1945

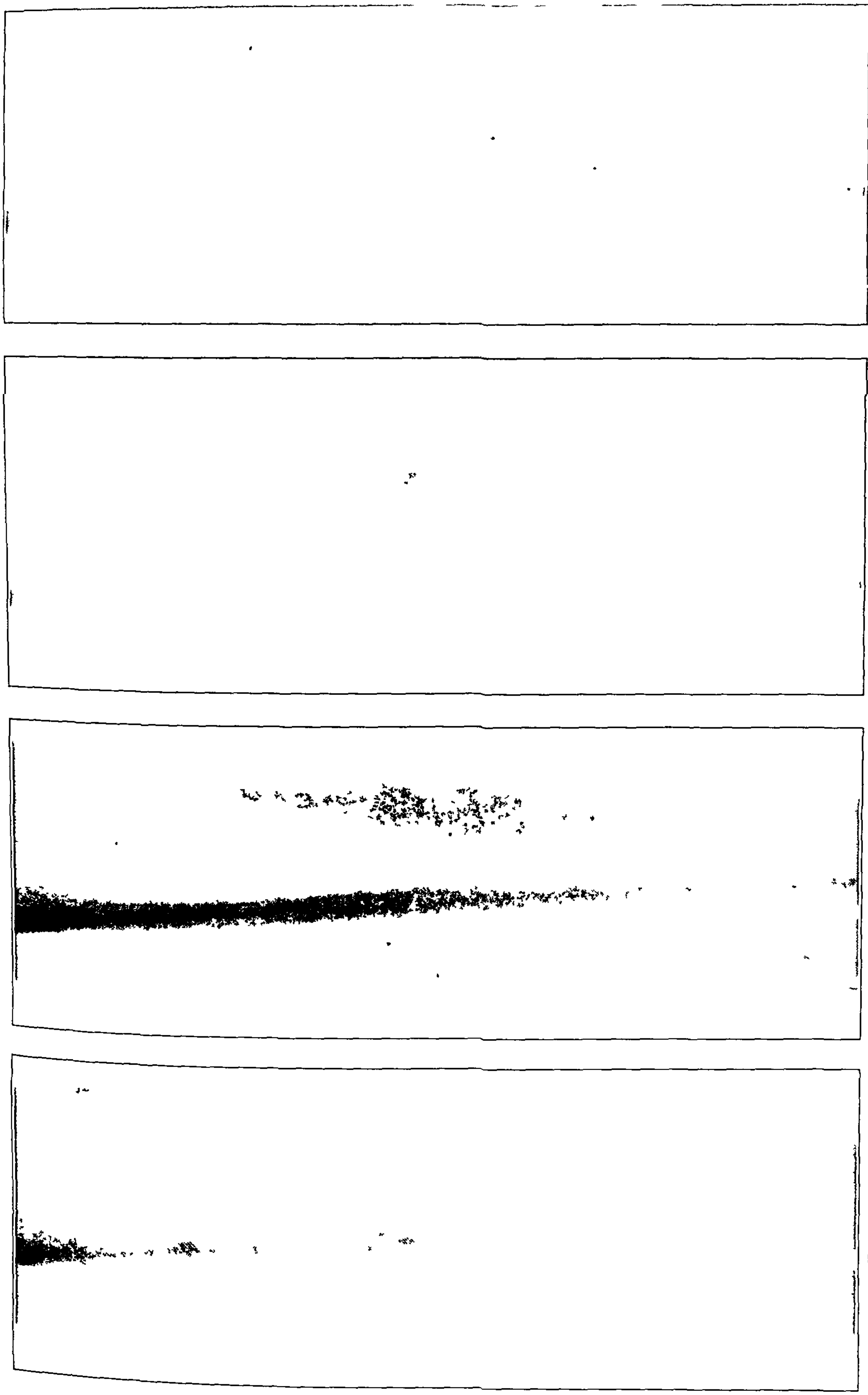

FIG. 2-B'
July 9, 1945

FIG. 2-C'
September 26, 1945

FIG. 2-D'
January 23, 1946

FIG. 2-E'
February 28, 1946

Development of cortical thickening (anteroposterior and lateral views). Note relatively "clear" areas of focus in Figs. 2-D' and 2-E'.

cells. The blood sedimentation rate showed a doubtful increase. The Wassermann reaction was negative on two occasions.

On March 1, 1946, a thick boat-shaped block of bone was removed from the tibial enlargement. The bone was extremely hard. On the deep surface of the exsected portion (which was divided across), a reddish wartlike excrescence was observed (Fig. 2-F). Swabbings from the bone surface laid bare by the exsection and from the deep surface of the exsected bone were sterile; bone shavings from the "saucerized" tibia produced a growth of a diphtheroid organism and a coagulase-negative *Staphylococcus albus* (both regarded by the bacteriologist as contaminants).

FIG 2-F
Exsected tissue.

The wound healed quickly. Pain ceased two or three days after the operation. At the end of May, the boy walked

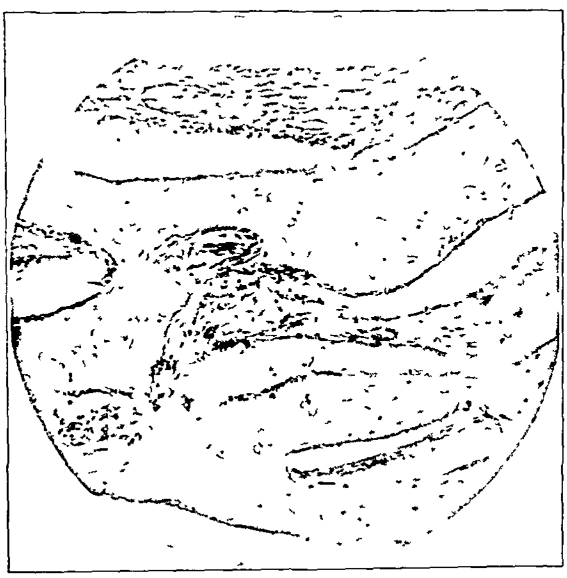

FIG 2-G
Dense portion, low-power photomicrograph.

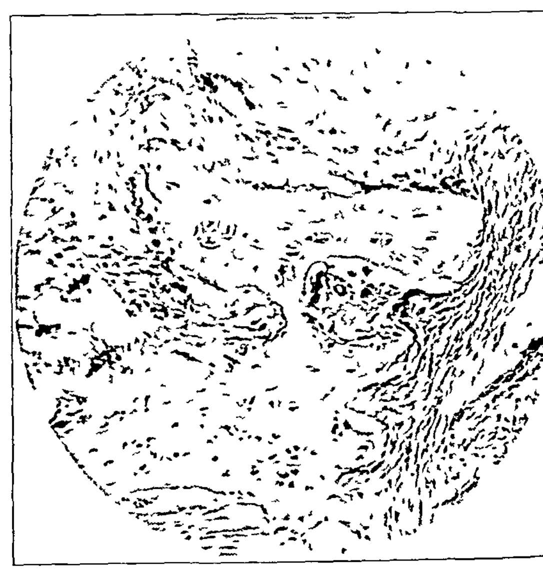

FIG. 2-H
Dense portion, high-power photomicrograph.

FIG. 2-I
Low-power photomicrograph of nidus. Rectangle indicates area selected for high-power photomicrograph.

FIG. 2-J
High-power photomicrograph of nidus. Multinucleated giant cells are shown in circled areas.

normally and admitted no disability. There was slight tenderness on firm pressure at the site of the bone exsection. Anteroposterior roentgenograms of the tibia at that date showed sclerosis and broadening; on the lateral view the deep excavation in the sclerosed and thickened bone was evident, but seemed less than it had been in March. The wartlike excrescence, mentioned previously, resembled the tissue described and illustrated by Jaffe and Lichtenstein (in their Case 3).

The exsected bone was examined histologically by Colonel W. F. Harvey, who reported as follows:

"The material was in two halves and consisted of dense, hard bone. One half showed a grooved central space, which contained a noticeable soft mass. This portion of the specimen was selected for section. Peripherally, the section [Figs. 2-G, 2-H, 2-I, and 2-J] shows fibrous tissue and periosteum, the fibrous tissue being loose and vascular and interspersed with fatty tissue, while the osteogenic periosteum is of the usual type,—cellular, fairly compact, and axially layered by osteoblasts.

"Under the periosteum there is a narrow layer of well-differentiated cancellous bone, the cancelli of which are wide, lined by osteoblasts, and contain, not bone marrow cells, but an oedematous-looking reticular-cell tissue which is probably the usual fibrofatty tissue of the marrow. This tissue is vascular—mainly capillary—and the vessels are turgid with blood. The dense cortical bone is succeeded by a central focus, which is approached by loose cancellous bone. The 'nidus' lesion is hemorrhagic and, in the section, is only a comparatively small area of tissue. Bone here is represented by an osteoid, trabeculate meshwork. The trabeculae are apparently osseomucinous (or chondromucinous), and the mucinous areas are lined by active osteoblasts. Moreover, the interstitial matrix to this immature bone is cellular, fibroblastic, and fasciculate. Multinucleated osteoclast cells are, in moderate numbers, easily recognized, but do not suggest osteoclastoma. The histological appearance of matrix, bone, and cells should rather be described as osteoclastoma-like, and as reminiscent of the areas sometimes found in association with osteitis fibrosa cystica (general and localized) and with single bone cysts. There is no microscopic indication of any inflammatory or septic reaction. Syphilis is in no way suggested by any endarteritis, necrosis, or plasma-cell abundance. Tubercle is, histologically, not in question."

SUMMARY

A special feature of these two cases of painful non-suppurative, non-inflammatory cortical thickening of the long bones is that the radiolucent area is not sharply outlined; in this it resembles the illustrative roentgenograms of Jaffe and Lichtenstein, and of others.

On microscopic examination, the bone focus removed in the second case resembled the histological description given by Jaffe and Lichtenstein.

No positive opinion is expressed regarding the essential nature and cause of the bone lesion in the two cases.

NOTE: Grateful acknowledgment is made to Dr. R. W. S. Harvey for the preparation of the photomicrographs.

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THE NEWER PATHOLOGICAL AND PHYSIOLOGICAL CONCEPTS OF ANTERIOR POLIOMYELITIS AND THEIR CLINICAL INTERPRETATION *

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It has become increasingly difficult to coordinate the great number of observations and studies which have been made on infantile paralysis, especially under the stimulus of The National Foundation for Infantile Paralysis, Inc. The clinical side has remained fairly well standardized for several decades; little that is essential has been added since Lovett and Lucas and Browning elaborated the clinical pathology. The interpretation of the clinical features of this disease, however, has been greatly enhanced by the newer studies in the fields of pathology and physiopathology.

PATHOLOGICAL STUDIES

In the field of pathology, the developments have been slow and laborious. The site of the lesion had been placed by Heine, in his later publications, as the spinal cord; but it was Charcot and Joffroy who recognized the anterior-horn cell as the principal seat of the pathological changes, even though they considered these secondary to interstitial changes. They also described, in autopsies, changes in the anterolateral white fasciculi of the cervical and lumbar regions. From then on the anterior-horn cells held the center of interest, and this was corroborated by many of the earlier autopsies, including those of Taylor and of Edes. The clinician had been depending entirely upon changes in the anterior-horn cells for his interpretation; it was on these grounds that the recession and intermission of the disease, remarkable and perplexing as it was, had been explained. The concept of the so-called "stunned" cell and of transitory oedema was thoroughly exploited.

That the disease is not limited to the anterior-horn cells has been known since 1908, when Cadwalader reported interstitial changes. He held, then, that the changes which terminate in the neuronophagia of the ganglion cells are primary. Lewis, in 1910, reported perivascular infiltration along the vessels in the gray matter, and involvement of the lateral and posterior horns in monkeys; he also found involvement of the white matter, the spinal-root ganglia, and the pia and arachnoid.

At the same time Sachs, who believed, as did Charcot forty years before, in primary interstitial and mononuclear infiltration, pointed out in his autopsies on the human that the changes were not limited to the anterior horn. He specifically called attention to changes in the "central gray matter", probably meaning what we now call internuncial pools; and he likewise found the posterior horns involved.

The picture was further clarified by reports of Jonnesco, who, in two autopsies, found the cells of the spinal ganglion involved in territories corresponding to the paralyzed regions.

Then came the contributions which pointed to the extension of the pathological process beyond the spinal cord. As early as 1910, Krause, who still believed in the secondary involvement of the ganglion cells, described inflammatory foci in the medulla, the pons, and the basal ganglia. A few years later Blanton confirmed in his fifteen autopsies the finding of changes in the basal ganglia and pons, but in twelve cases examined he found the cortex and the cerebellum normal. In fact, none of the subsequent reports on pathological findings failed to include structures of the cord other than the anterior-horn cells, as well as other portions of the central nervous system outside of the cord. Warburg, for

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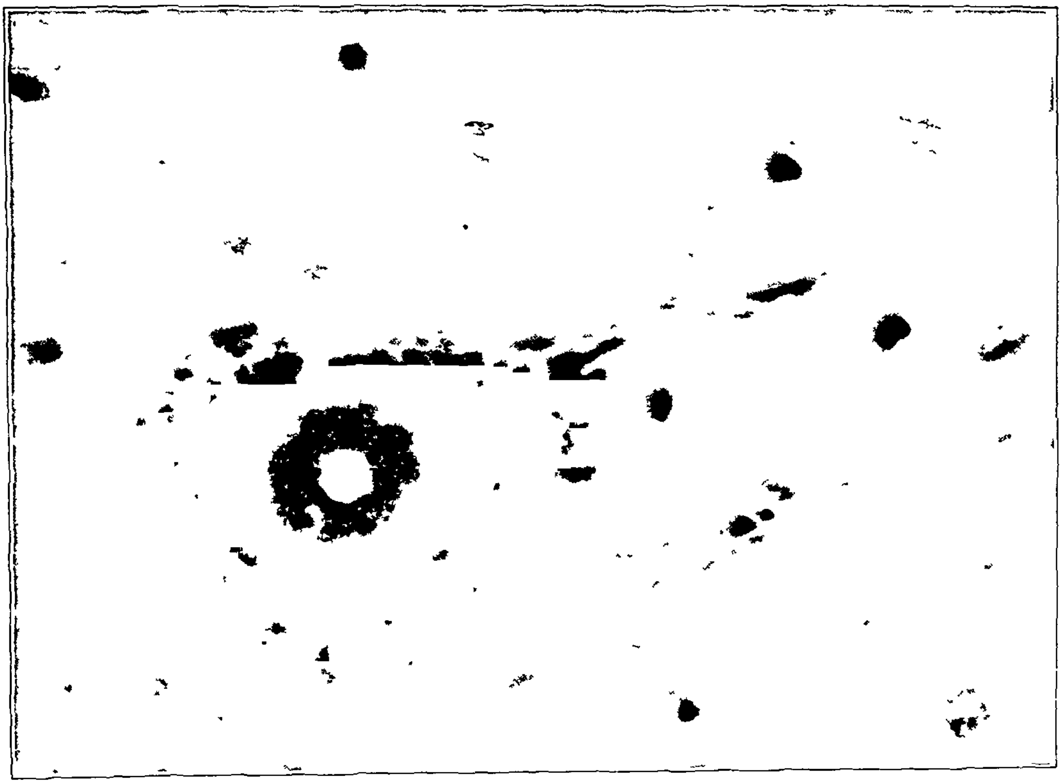

Fig 1

Normal anterior-horn cell (× 792) Notice large Nissl bodies distributed throughout the cytoplasm, numerous cell processes with a few Nissl bodies in the axon, and the central location of the nucleolus.

instance, mentioned lesions in the cord and the spinal ganglia, the medulla oblongata, the pons, the mid-brain, and the basal ganglia, as well as the cortex and cerebellum, variously interpreted as inflammatory, degenerative, or regenerative. As far as the relative origin of these changes is concerned, Környey stated that, cranially from the medulla oblongata, the changes were mainly mesodermal and glial, which means interstitial, while the main seat of the parenchymal lesions remained in the anterior-horn cells. In the cortex, the mesodermal changes are the first sign of the poliomyelitic process, and there is a definite selectivity as far as the area and layer of the cortex are concerned,—namely, the large, or giant cell, fifth layer in the motor area[16]. In these higher regions, the infiltration of neuroglial cells and lymphocytes is far more extensive than the changes in the motor-nerve cells themselves.

Further evidence has been given of lesions cranially from the medulla to the mid-brain and the basal ganglia. The report of Peters on seventeen autopsies showed that changes occurred, not only in the anterior horn, but also in the posterior and lateral horns and in the intermediate zone (later called the internuncial pool) and cranially in the nucleus ruber, in the substantia nigra of the pons, and almost regularly in Deiters's nucleus

The motor cells are more often and more extensively involved than the sensory cells, but this selective affinity of the virus for cells of the motor type is not absolute. Swan found the sensory ganglia—spinal as well as cerebral—the thalamus, and the hypothalamus involved. Sabin described the constant changes in the neural connections between the alimentary tract and the central nervous system.

Thus it becomes evident that, since Charcot's time, pathological studies have led to a gradual extension of our concept of the seat of the disease. This concept now covers many parts of the central nervous system, and it is much more adaptable for an explanation of clinical symptoms and course.

The selectiveness of the paralysis, and the prevalence of the partial over the total paralysis of muscles, to which Lovett has already called attention, suggest a spotty focal

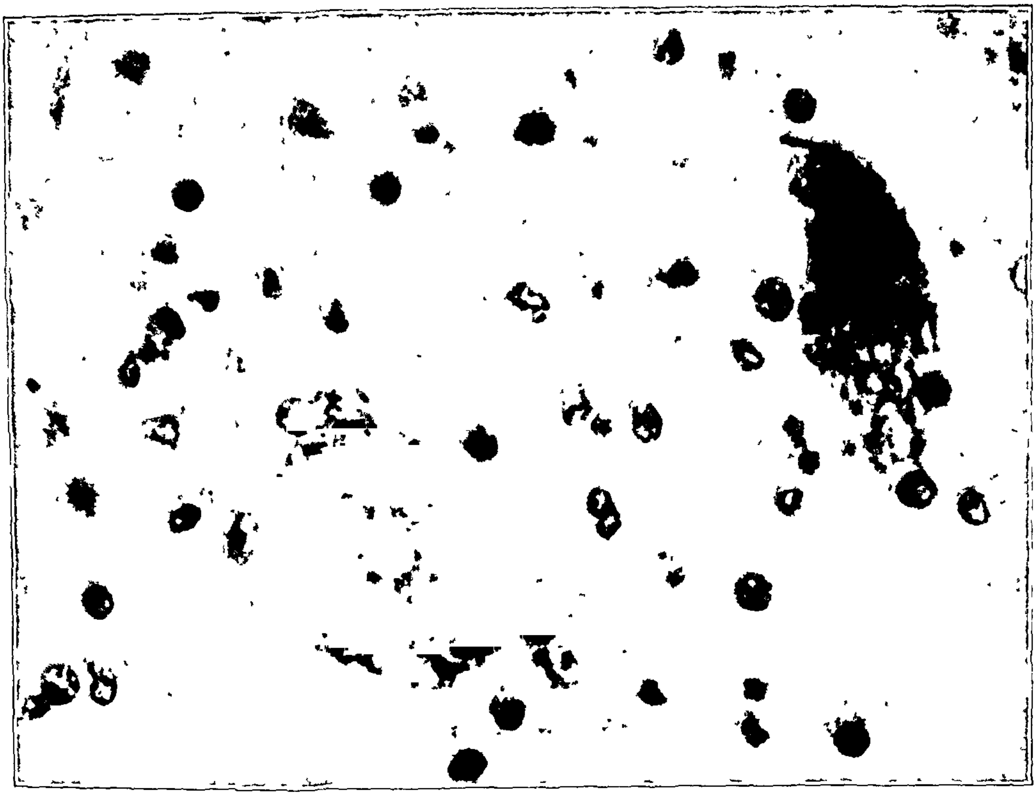

Fig. 2

Section of an anterior-horn cell (× 422), showing early central chromatolysis, in acute poliomyelitis. Nissl bodies are fragmented and have largely disappeared from the center of the cells. Microglia cells and lymphocytes are evident. Infiltration or inflammation in this region of the anterior horn is mild.

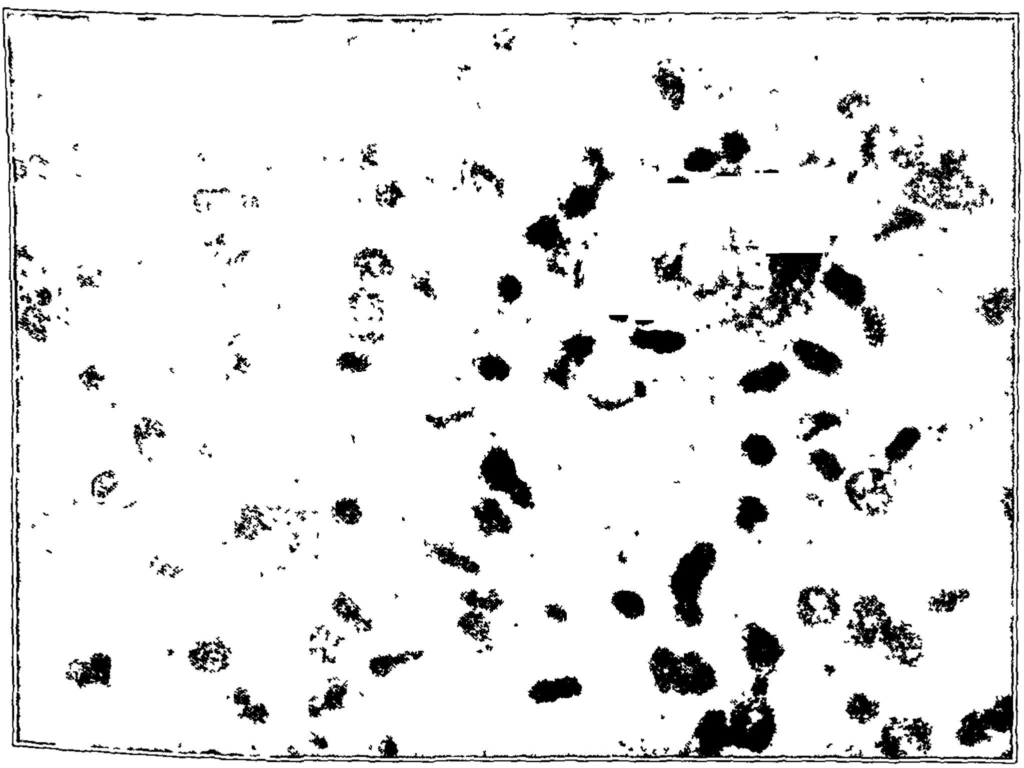

Fig. 3

Section (× 422) from the lumbar segment of the cord in a case of acute poliomyelitis, showing central chromatolysis of the anterior-horn cell, with fragmentation of the cell walls. Notice almost complete loss of the Nissl bodies and peripheral location of the nucleolus. This area of the anterior horn is densely infiltrated with inflammatory cells.

FIG. 4

Section (× 422) of an anterior-horn cell, showing early central chromatolysis, in a case of acute poliomyelitis Same pathological changes are present as in Fig. 2.

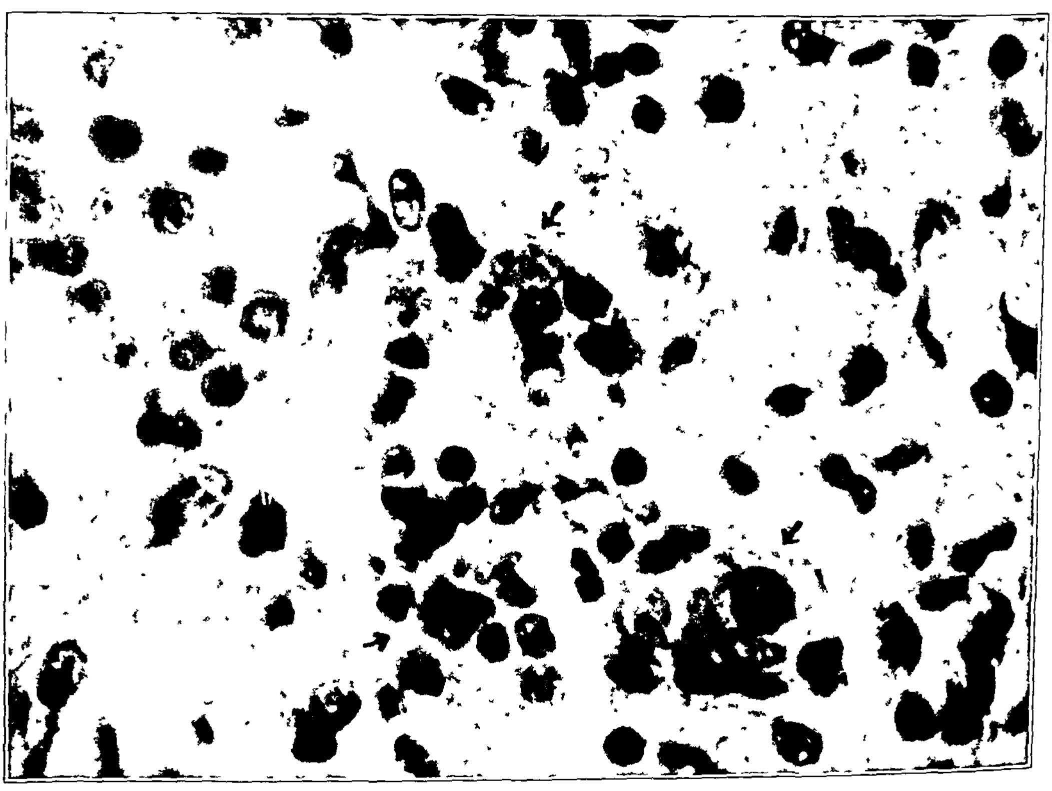

FIG. 5

Satellitosis of the anterior-horn cells. Three anterior-horn cells which have been fragmented are seen in this photomicrograph (× 422). The nucleoli and cell remnants are surrounded by monocytes or macrophages; microglia cells and lymphocytes are scattered throughout.

involvement of the cord. In cases of early arrested and non-paralytic poliomyelitis in monkeys, Bodian and Howe found minimum changes, which consisted of discrete regional

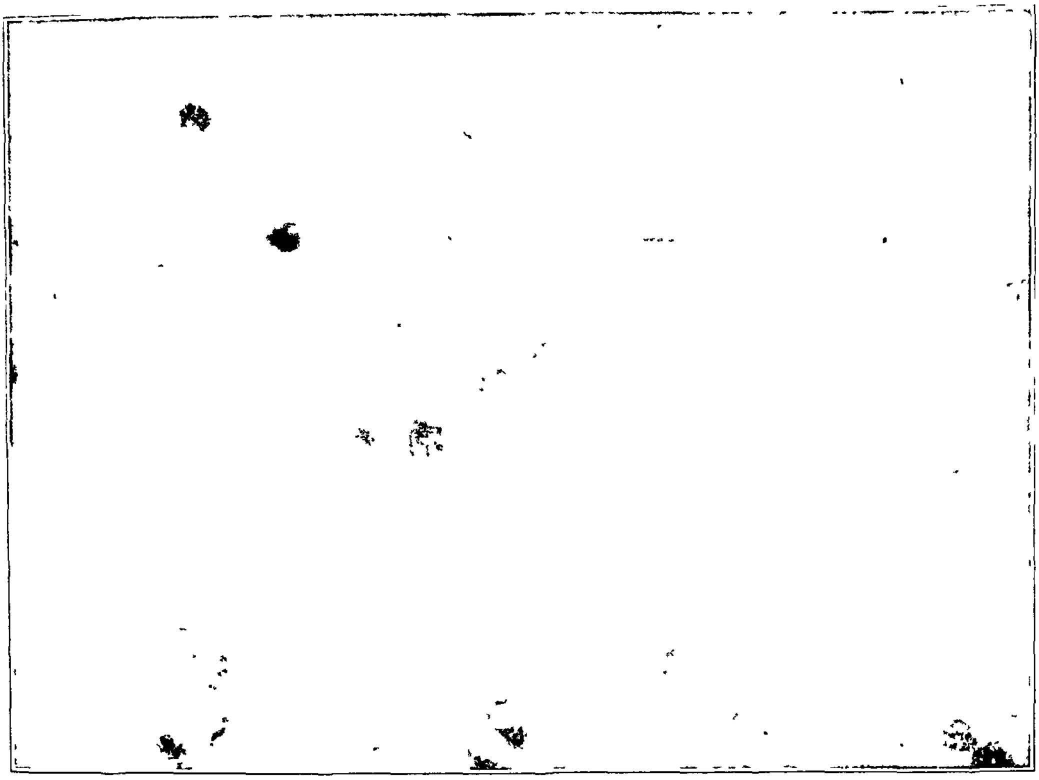

FIG. 6
Normal intercalated or internuncial neurons. These cells have fewer processes and smaller masses of chromatin matter, and are smaller than anterior-horn cells. (× 792.)

destruction of neurons with mesodermal glial infiltration and cuffing. The absence of clinical paralysis is due to the scattered distribution of the motor-neuron lesions.

Many years ago this so-called focal distribution[23] was studied from the anatomico-topographical point of view by Sano and Bruce.

In the cross section, certain clusters of motor cells appear in the cervical and lumbar intumescence in the lateral portion of the anterior horn, in addition to the constant and segmental clusters which occupy the more medial portions. As more muscle groups appear, these additional clusters are added in such a fashion that the more distal muscle groups have their nuclear representative in the increasingly lateral portions of the anterior horn; this is similar to the motor and sensory arrangement in the precentral and postcentral gyri of the cortex.

Of still greater interest is the perpendicular arrangement, in which these clusters appear as columns. It seems plausible that the destruction of a cell cluster in a given cross section may mean little or nothing to the function of the muscle, which is supplied by a certain nuclear column. The medullary nuclei of some of the muscles spread over a number of spinal segments, while others (for instance, the tibialis anterior) spread over a few only. This may explain why some muscles are more likely to escape complete paralysis than others.

Analysis of the 1000 cases of paralysis of the lower extremities, collected by Sher, shows that the tibialis anterior was severely involved in 83 per cent., the tibialis posterior in 79 per cent., the gastrocnemius in 62 per cent., and the peronei in 66 per cent., to mention only the muscles most frequently involved. On the grounds of the topographical extension of these columns, one may explain the relative frequency and degree of involvement of single muscles or of muscle groups. However, to the author's knowledge, Sano's diagrams have not yet been confirmed by serial sections of the cord.

The second point of clinical interest is recognition of the reversibility of the anterior-horn lesions (Fig. 1). Obviously, complete destruction of the anterior-horn cells is final

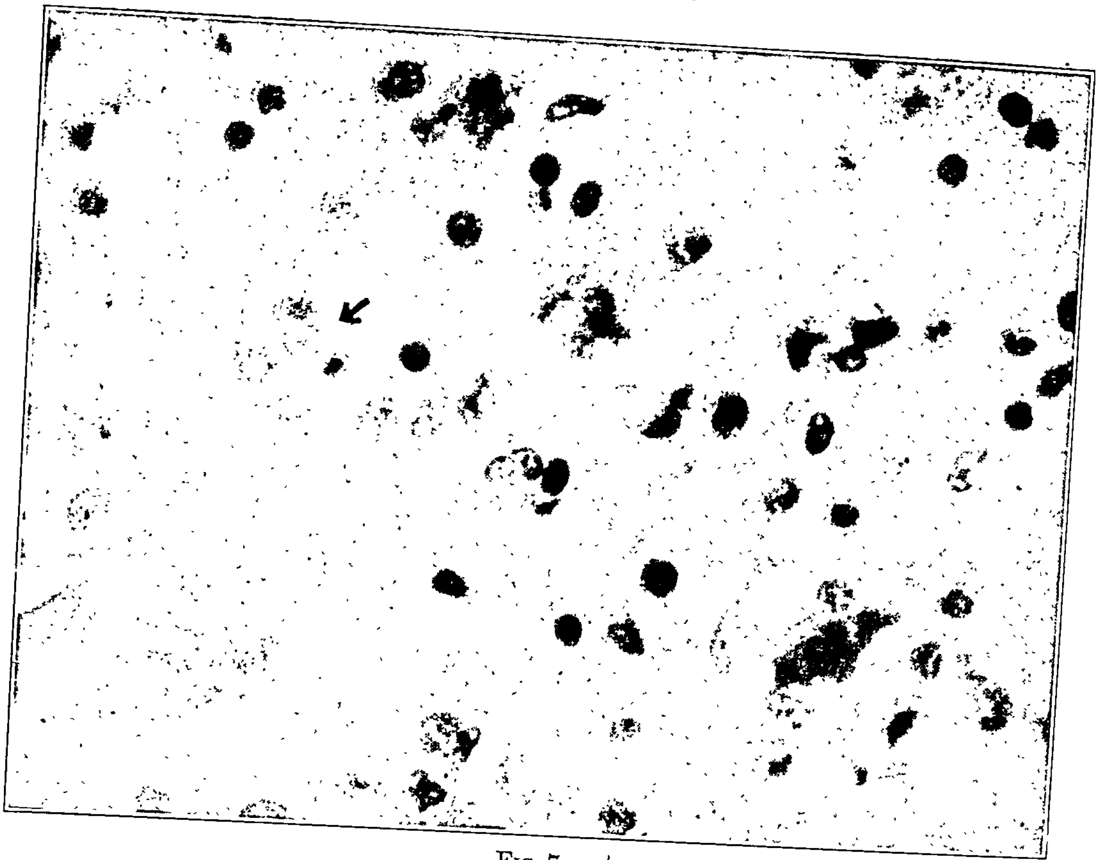

FIG. 7

Intercalated neurons, showing chromatolysis and satellitosis. Notice the marked chromatolysis of the neurons, with a moderate number of inflammatory cells present. The arrow indicates an intercalated neuron that has succumbed; only the nucleolus remains. Macrophages, like vultures, surround this remnant. (× 422.)

FIG. 8

Section from the lumbar cord in acute poliomyelitis. A low-power photomicrograph (× 106), showing the infiltration of microglia and lymphocytes and the perivascular cuffing which exist throughout the gray and white matter of the cord, in some areas. The pathological changes are not limited to the anterior gray column.

Fig. 9

Section (× 106) from the lumbar cord in acute poliomyelitis, showing necrosis and hemorrhage of the anterior horn. Notice the dense infiltration of inflammatory cells throughout this area. Tissue continuity has been lost in the central portion, due to necrosis, and hemorrhage has occurred.

and permanent damage; yet up to a certain point the changes seen in these cells must be reversible, just as the inflammatory glial infiltration and the perivascular lymphocytic exudates or cuffs are reversible. This is essentially the sequence of changes (Figs. 2, 3, 4, and 5) in the motor cells of the horn, which was known to Cadwalader in 1908 and Wickman in 1909: the chromatolysis, the sharply outlined acidophilic inclusion, or the Nissl bodies, and the peripheral arrangement of these bodies; then the loss of cell outlines, complete disintegration and crumbling of the cell, followed by satellitosis of the nucleus; phagocytosis; and finally gliosis.

Patton distinguishes three phases: The first is the early swelling of the cell with enlargement of the nucleus and disappearance of the Nissl bodies. The second is the chromatolysis with basophilic granules filling the cytoplasm. The final stage is the breaking up of the cells, with necrosis.

If there is a certain degree of reversibility of the changes in the motor cells of the horn as they exist in the secondary reaction of glial infiltration and perivascular cuffing, it furnishes a plausible explanation for the complete recession of paralysis, just as the focal distribution of poliomyelitis in the columns of motor cells in the anterior horn explains all degrees of partial paralysis.

The next clinical symptom to be explained on pathological grounds is the spasm, which has become the most controversial feature of all. It is now believed that spasm represents a dysfunction of the intermediate, or so-called internuncial, cell group of the anterior horn. Neurologists have known for a long time[21] that there is a synaptic relay group, both motor and sensory, situated dorsal to the cells of the anterior horn (Figs. 6 and 7). All impulses going through the spinal reflex arc, as well as those coming down from higher centers, are relayed through these cells to the motor neurons of the anterior horn.

Kabat and Knapp have attracted wide attention by a report on the pathological findings on not less than seventy-eight patients, who died as a result of poliomyelitis. They regularly found lesions of this intermediate cell group; and furthermore, in 40 per cent. of

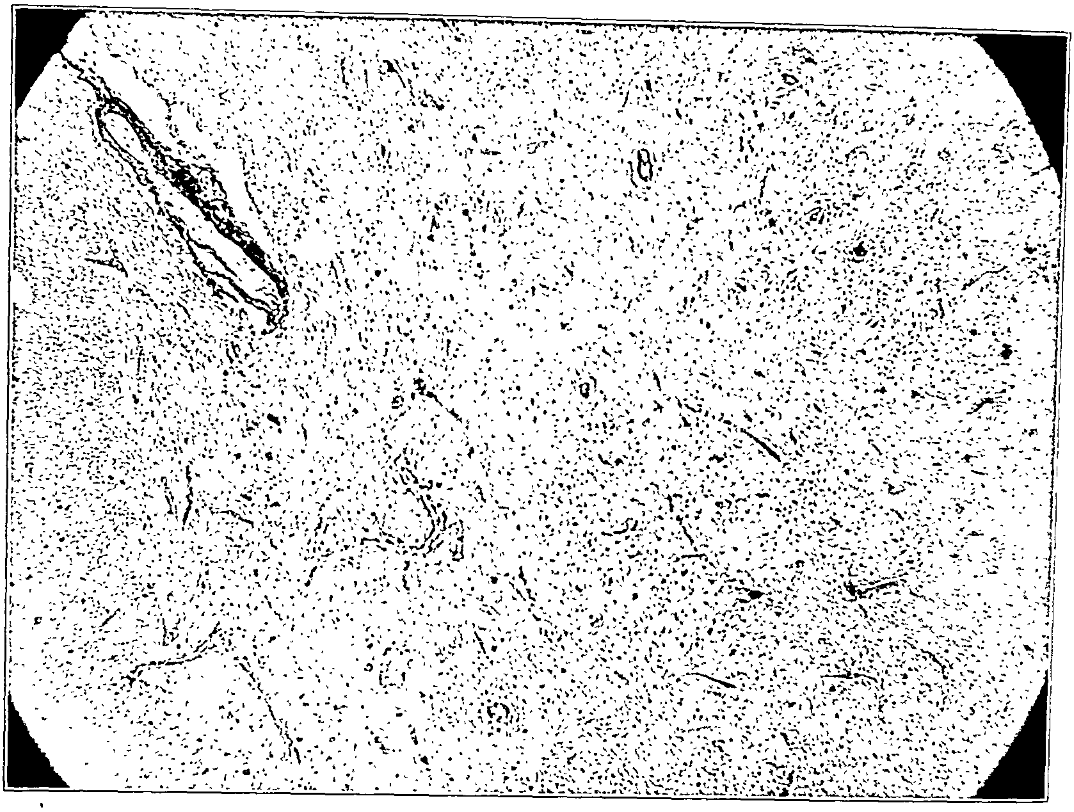

FIG. 10

The lumbar cord following acute poliomyelitis, showing gliosis of the anterior horn. No semblance of the anterior horn remains. Scar of gliosis completely replaces most of the area. (× 100.)

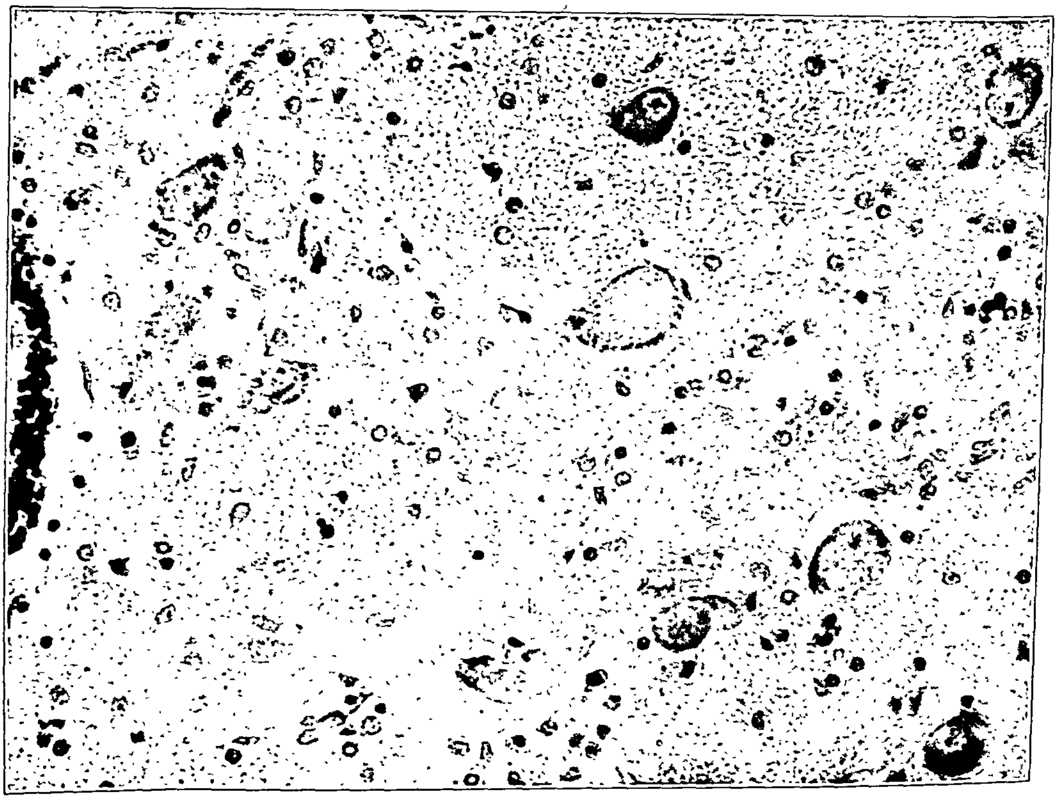

FIG. 11

Area of the medial vestibular nucleus in the floor of the fourth ventricle in acute poliomyelitis. Notice perivascular cuffing, central chromatolysis of the neurons, with peripheral location of the nucleoli, and infiltration of lymphocytes and microglia cells. (× 422.)

their cases, the internuncial cells alone were involved, while the cells of the anterior horn were intact.

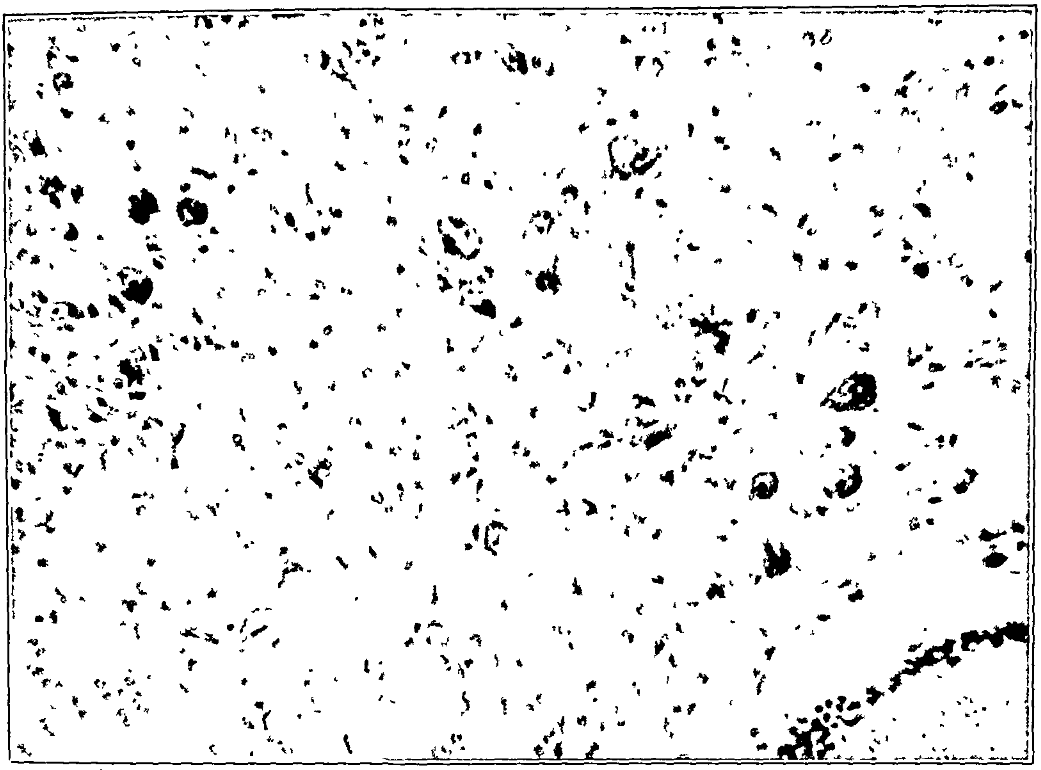

FIG. 12

Area of the medial vestibular nucleus in the floor of the fourth ventricle (× 422). The conditions are similar to those present in the case shown in Fig. 11.

Unless these findings are based upon serial sections, it would not necessarily mean that the anterior-horn cells have entirely escaped destruction, except at a certain level.

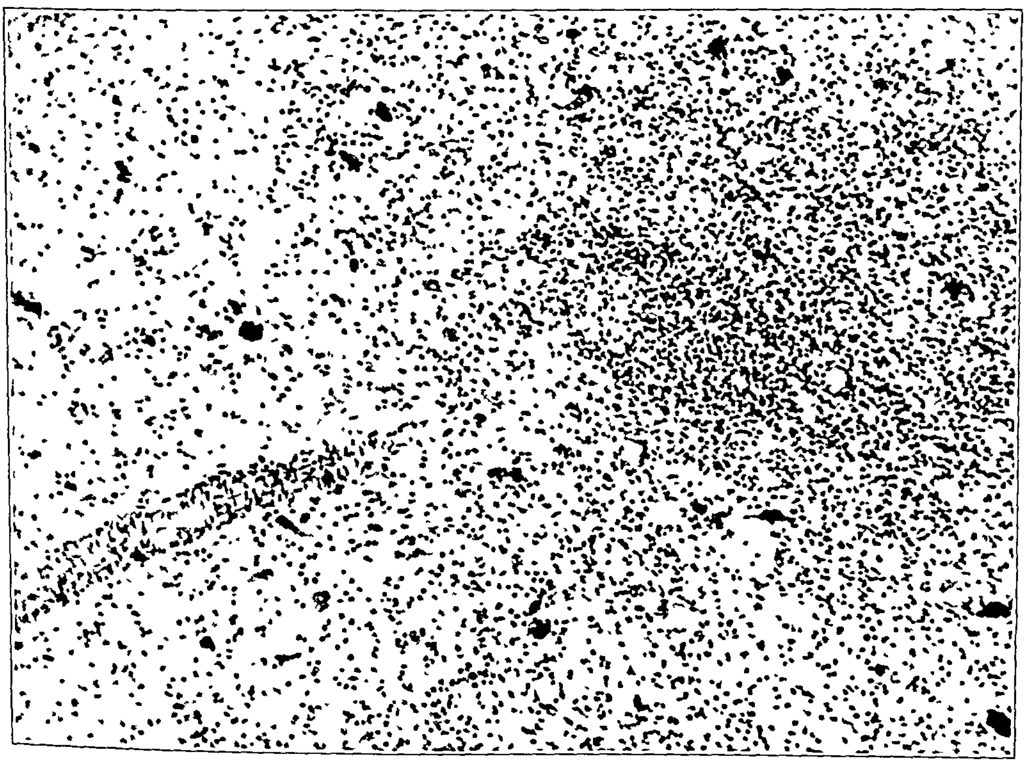

FIG. 13

Section (× 422) from the mid-brain in acute poliomyelitis. The same type of inflammation noted in Fig. 12 is present here, also. Notice the microglial and lymphocytic infiltration and the perivascular cuffing.

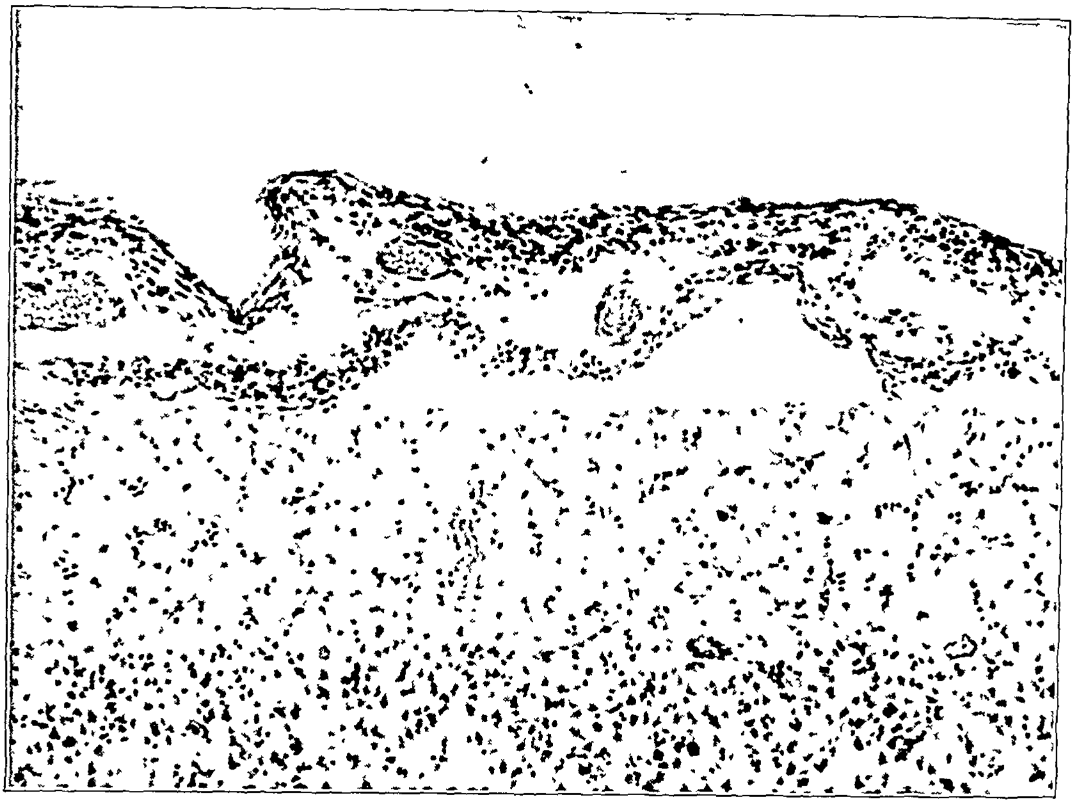

FIG. 14

Section (× 422) of the meninges of the brain in acute poliomyelitis. The meninges have become thickened by the inflammatory process. Dense infiltration of lymphocytes and mild perivascular cuffing are present.

n the author's small series, anterior-horn cells were found to be destroyed, either alone or together with the internuncial cell, but not the reverse (Figs. 8, 9, and 10).

The clinical corollary of this internuncial-cell lesion is believed to be the spasm. There is no doubt that it is a most frequent symptom, and that it is entirely different from contracture. During the 1944 epidemic in Iowa, the author found spasm in practically all cases, and almost invariably in the quadriceps. Even though the muscle was incapable of active contraction, it felt hard and indurated; and attempts to flex the knee caused pain, referred to the muscle and not to the joint. Thus, if we admit the role of the internuncial-cell group, spasm would appear not to be a phenomenon of the lower motor neuron at all, but would belong to the higher regulatory, or inhibitory, centers.

Consideration will now be given to the lesions in the higher centers,—namely, the medulla oblongata, the pons, the basal ganglia, and the more recently described changes in the tegmental regions of the mid-brain (Figs. 11, 12, and 13). Peers described, in the paracentral gyrus, perivascular cuffing, lymphoid infiltration, and thrombosis of the vessels. He observed that these changes, as well as the others in the tegmental nucleus, are reversible and transitory, and that they decrease in monkeys as time elapses. Bodian injected poliomyelitis virus intracranially into three monkeys, waited for spasm to develop, then killed the animals. He found lesions in the basal ganglia, but none in the cord. The occurrence of these lesions may well be in harmony with the phenomenon of incoordination and asynergic contraction of muscles—a disturbance of the normal reciprocal innervation—as is postulated by Sherrington.

It is not beyond the realm of possibility that the symptoms of so-called "mental alienation", as Miss Kenny calls it, represent the loss of voluntary cerebral control, a physiological block within the central nervous system, and, more specifically, in the system of synapsis located all the way from the cortex to the cord. While we recognize this as a transitory and reversible stage, it may for all practical purposes appear as a real paralysis. In contrast, however, to the changes due to the destruction of the anterior-horn cells, these

changes are entirely reversible; and this may well explain some of the early and remarkably rapid cures, now ascribed to our own handiwork (Fig. 14).

It must also be considered that not all cerebral lesions are necessarily reversible (Fig.

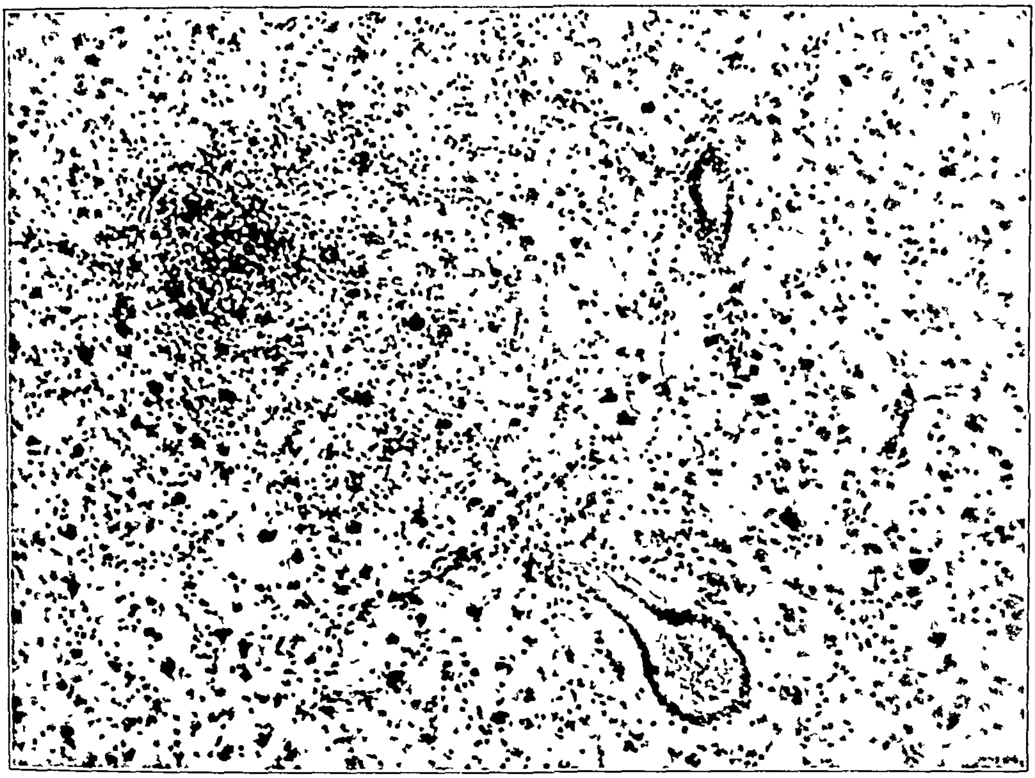

Fig. 15

Section (× 422) showing the fourth layer of the cerebral cortex in acute poliomyelitis. The same type of inflammation is present as in Fig. 14.

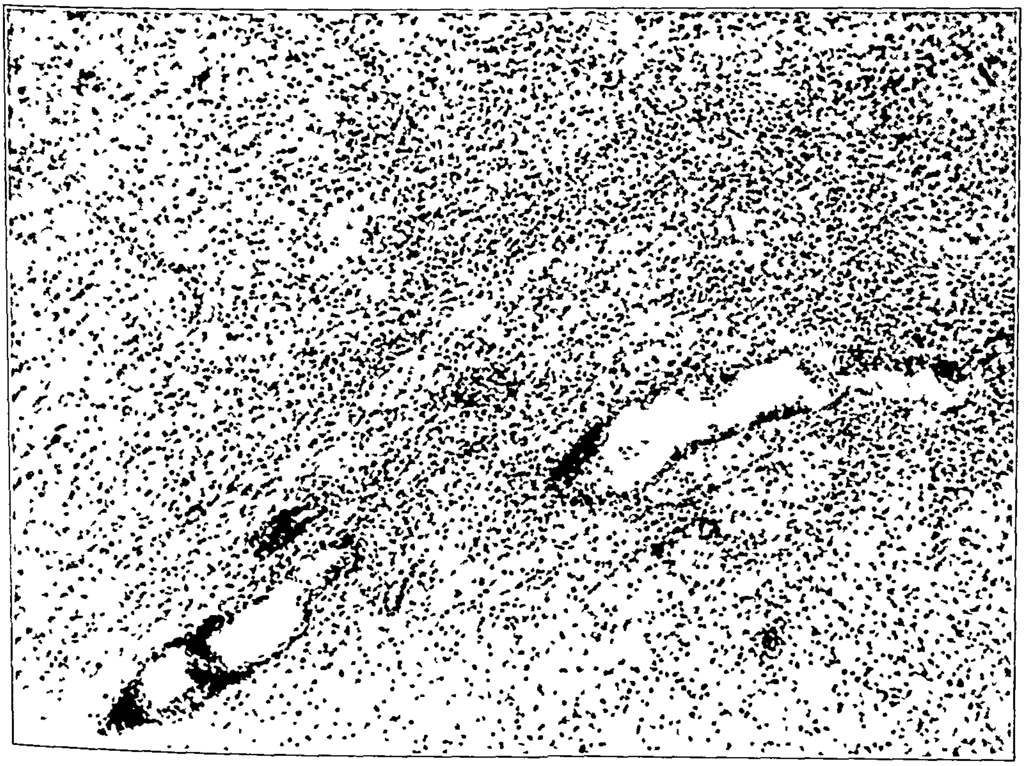

Fig. 16

Section (× 422) of the posterior horn of the cervical spine in acute poliomyelitis. Massive infiltration of microglia cells and lymphocytes is present, with perivascular cuffing.

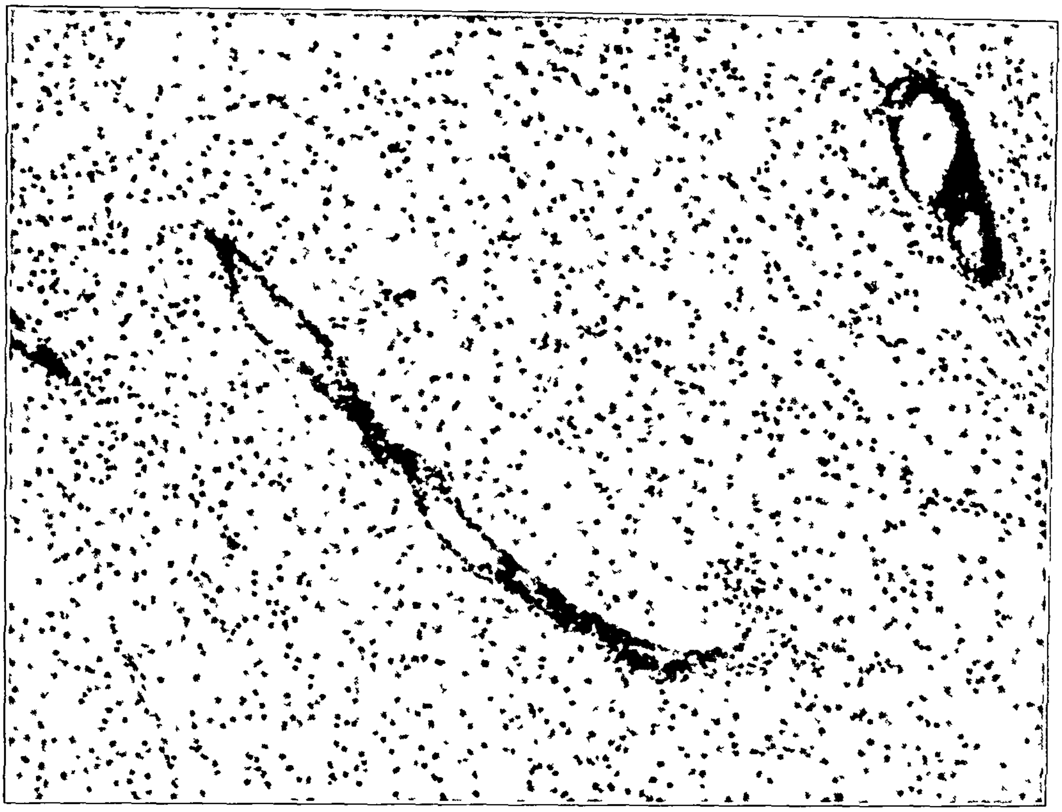

Fig 17

Section (× 422) of the posterior horn of the lumbar area of the cord in acute poliomyelitis Notice dense inflammatory reaction present in this portion of the cord.

15). This is illustrated in epidemics or solitary instances of infantile paralysis, where the residual symptoms are not paralysis or shrinkage of the muscles, but fatigue, incoordination, and lack of concentration,—features which point distinctly to the cortex and which make it difficult to draw a strict boundary line between poliomyelitis and polio-encephalitis

The question arises of what is the pathological equivalent to the sensory symptoms of pain and skin irritability.

Small foci of infiltration of the dorsal root in the sympathetic ganglia have been recognized for decades. Sachs, on the basis of eight autopsies, described changes in the central gray matter,—evidently the internuncial cells, as well as changes of the posterior horn (Figs. 16 and 17). More recently, Toomey expressed the belief that the first cellular reaction is probably destruction of the cell elements of the spinal ganglia; and he also reported involvement of the lateral horn, which is subserving the autonomic system From our clinical observations, these sensory lesions represent reversible changes. Whether or not true lesions of the sympathetic system exist is still undecided. From the clinical point of view, their occurrence is not unlikely. We refer here to the changes in circulation often seen in severe cases. From our own observations with sweating, and from other tests[41], hypohidrotic, vasodilatory, and hypopilomotor changes have been found. These are hard to explain, except on the basis of functional insufficiency of efferent sympathetic nerves

PHYSIOPATHOLOGICAL STUDIES

Studies in physiopathology have been carried on in recent years, and the center of interest is held by the muscle and the neuromuscular junction.

However, John Ridlon, more than fifty years ago, pointed out that within a short time the affected muscle begins to become atrophied, and he stated that there is nothing in this change to distinguish it from the atrophy of disuse. This statement established the distinction between simple atrophy and degeneration, which is necessary in order to understand the subsequent relations of neuromuscular regeneration. That a muscle can recover

from an advanced stage of simple atrophy and that it could not recover from a similarly advanced stage of true degeneration has already been amply indicated. As Aycock aptly puts it, the doctrine of pleurisegmental innervation of the individual muscle fibers (in accordance with the topographical scheme of Sano) offers the most adequate explanation of the phenomenon of recovery.

The histological corrollary of regenerability of the muscle fibers has been studied. Simple atrophy shows a shrinkage of the fiber, and an apparent, but not a real, increase of the sarcolemma nuclei; later there is a disappearance, first, of the cross striation, and then of the longitudinal striation. It is believed that these stages are still reversible. The more advanced changes in the muscle begin with vacuolation, necrosis, and crumbling of the sarcoplasm, and proceed to proliferation of the interstitial tissue, and, finally, to fibrous or fatty substitution of the parenchyma. These latter changes are believed to be irreversible.

The next problem was to find the physiological responses which correspond to the different phases of muscle atrophy and degeneration.

Physiologists have been interested in the action current of the paretic muscles. Proebster made the significant finding that there was no parallelism between excitability and tension strength of the paretic muscles. The excitability may be 100 per cent. of normal, whereas the contractive strength may be only a fraction of it. Furthermore, Proebster spoke of the state of permanent excitation of the paretic muscle, which entails the danger of early fatigue. The poliomyelitic muscle may have as low a threshold of excitability—that is, response to small stimuli—as does the normal muscle, but the important point is that, when it does respond, it responds with a maximum oscillation.

It is of significance that, in true muscle degeneration, there is a retardation of the appearance of action current on voluntary contraction; but this could not be demonstrated by Proebster in the majority of poliomyelitic muscles, which evidently were in the state of simple atrophy. The paretic muscle of poliomyelitis, on continuing voluntary innervation, produces action-current curves which correspond to maximum effort, and consequently are likely to lead to early fatigue. In this latter case there appears, then, the picture of incoordinated action-current curves, with low amplitudes and exhaustion.

These earlier action-current experiments are mentioned because they fit in so well with the recent investigations carried out by Bouman and Schwartz. These authors showed in the electromyograms that spasm exists not only in the antagonist, but also in the weakened muscles. However, spasm does not exist in the totally flaccid paralyzed muscle. Furthermore, Bouman and Schwartz found that the paretic muscle-current potential increases with the improvement in motor power. These findings seem to prove that spasm is a general phenomenon in infantile paralysis, occurring in the earlier stages of the disease. It appears in the synergist and antagonist alike, and has nothing to do with denervation of the motor horn. It finds a plausible explanation in the dysfunction of the internuncial-cell group, which has lost its inhibitory effect on the spinal reflex mechanism.

The understanding of the neuromuscular dysfunction of the poliomyelitic muscle has been further advanced by experiments on chronaxia, which means the time necessary for a current of standard intensity—that is, twice the minimum rheobasic current—to produce muscle responses. These experiments are not new. As early as 1928, Marinesco, Sager, and Kreindler conducted such investigations on muscles in infantile paralysis. Péhu and Morin found in eight cases, during the first days of poliomyelitis, a moderate increase of chronaxia values in the affected muscles, which values reached their maximum in a few weeks. Then, as the muscle recovered, the values came down in from two to eight months. The time of evolution and the intensity of these chronaximetric disturbances were found to be proportional to the severity of paralysis. Also, Chauchard and his associates found that, in monkeys, the chronaximetric changes appeared earlier than the paralysis, which indicates an early encephalitic involvement.

Foremost in the investigations along this line stand those of Moldaver, who emphasized the electroprognostic value of chronaxial measurement in this disease; he believed that these measurements offered the best index of functional recuperation. He showed that muscles in spasm have normal chronaxia values. Neuromuscular degeneration can be determined by chronaxia, while spasm does not lead to neuromuscular degeneration. The muscles with only slightly increased chronaxia time have a good prospect of recovery, while those with prolonged chronaxia or those not responding at all offer a poor prognosis.

Recently, experimental physiology has taken another helpful step in the interpretation of symptoms concerning muscle tone and muscle volume. We have known that fatigue is under the influence of the central nervous system and it is not connected with the neuromuscular unit itself,—at least, in the healthy muscle. Proebster has already pointed out that the considerably atrophic and shrunken poliomyelitic muscle requires, even for a moderate contracting effect, a maximum expenditure of energy. Therefore, fatigue will set in much sooner in such a muscle.

The impulses, which in the normal muscle are imparted sufficiently by the cord or by higher reflexes, require in the paretic muscle a sustained and conscious energy effort; hence early fatigability results. In addition, the experiments of Orbeli showed that fatigue can be retarded by stimulation of the sympathetic nerves.

Orbeli's experiments do not, however, parallel the clinical situation, which can be correlated much better with more recent experimental findings. These findings have changed former ideas about the fatigability of weakened muscles, and it is no longer believed that absolute immobilization is necessary to save a weakened muscle from exhaustion.

The experiments of Hines and his associates at Iowa University [15,22,51] showed that, owing denervation, the failure of the muscle to develop effective tension is the cause of atrophy; they also found that inactivity and immobilization retard neuromuscular regeneration, while, on the other hand, a program of early muscle use promotes it. These authors further found that electric stimulation, of the order required for maximum tension and for maximum physiological stretch, greatly retarded the loss of weight and the loss of strength of the muscle in the period which preceded its re-innervation. Finally, they found that not even the resultant fatigue seemed to have an injurious effect on any phase of neuromuscular regeneration.

The application of these newer discoveries to the clinical interpretation of symptoms and to the policies of treatment is far-reaching.

Because of the high incidence of spontaneous recovery, any therapeutic measure would be hard to evaluate. In addition, improvement in muscle function may not all be due to recovery of a nerve cell from shock or other reversible change within the cell itself, but it may be due to hypertrophy of the remaining uninvolved muscle fibers.

From the standpoint of treatment, spasm is considered to result from loss of the inhibitory action of the internuncial-cell group and of the higher centers. With this idea in mind, Kabat and Knapp introduced prostigmine, because they believed that it not only reduced the hypertonus of the skeletal muscles and the proprioceptive reflex hyperirritability, but it also reduced the incoordination, which would indicate that this drug acts upon the higher centers, also.

Prostigmine may not find general use in poliomyelitis, since the spasm and the hyperirritability are transitory symptoms. The author's experience is too limited as yet to justify on opinion; but, from the experimental side, Hines and his associates found neither a delay nor a hastening of the neuromuscular regeneration after prostigmine injection.

Physiological Effect on Nerve Regeneration

A recent plan to promote nerve regeneration is the so-called nerve crushing, or neurotripsy. The idea is not entirely new. In 1935, Iovino produced, experimentally, paralysis of the sciatic nerve by cutting the nerve partially and then resuturing the cut end. Within

three months the function of the leg reappeared; it became normal in six months, and the muscle atrophy disappeared. Iovino reported that after ten months there was an actual increase in the sutured nerve fibers over those of the normal sciatic nerve on the other side. The regenerated surplus nerve fibers were uniformly distributed in the entire peripheral end of the sectioned sciatic nerve.

In line with this concept of hyponeurotization, Billig, Van Harreveld, and Meersma studied the regeneration of nerves after nerve crushing. Experiments were carried out on rabbits. The quadriceps was made equally paretic on both sides by pulling out some of the spinal roots of its nerve supply. The authors then proceeded to crush the remaining fifth lumbar root on one side, leaving the root on the other side intact. They found that, after the crushed root had regenerated, there was actually an increase of muscle power on the side of crushing over that on the other side. The underlying idea was that the regeneration after crushing not only equals, but actually exceeds, the supply of axis cylinders and neuromotor end-plates over and above the supply present before the crushing.

This principle was then applied to patients with partially paralyzed muscles; the crushing of their motor nerves was done either openly, near the motor points of the muscle, or subcutaneously, with an instrument which resembled a compressed-air riveter. The improvement of the muscle power was carefully measured, according to a standard grade scale and by electromyograms. A number of patients who have been interviewed by the author expressed themselves as having definitely been benefited by the procedure. According to Hines and his associates, the maximum recovery after crushing, measured by muscle weight and tension, is about 85 to 90 per cent. It is remarkably constant, and reaches its peak in about twelve weeks. Nevertheless, no admission has yet been secured from physiologists that, following nerve crushing, the amount of regenerated nerve supply exceeds or even equals the normal.

TREATMENT

In summary, these more recent studies in the pathology and physiopathology of muscle and peripheral nerves do not seem to have brought about anything resembling a complete and radical change in the management of anterior poliomyelitis; they have, however, produced important modifications in our concepts of conservative treatment.

Rest

The application of heat and rest and the avoidance of stretch reflexes in the affected muscles are still being adhered to, along the lines laid down by Lovett; in addition, during the period of hyperaesthesia, all limbs are kept in proper position. The technique of heat application has been vastly improved by Miss Kenny, and the results are particularly striking in such conditions as intercostal rigidity, spasm of the neck and back muscles and of the hamstrings, and quadriceps rigidity.

Immobilization

Casts are almost never used, and braces for the protection of joints are applied only to prevent deformity. Weight-bearing is allowed as early as possible, and recumbency is prolonged only in patients threatened with spinal asymmetry.

Movement

It is especially important to keep up the muscle tone by early massage and by systematic active and passive movement. The fear of exhausting or permanently damaging a muscle by taking it through the full range of motion is, in the light of experimental evidence, without foundation.

It has been established that early mobilization favors, rather than impedes, neuromuscular regeneration. This applies to the so-called "alienated muscle", which Moldaver has shown, on grounds of chronaxial changes, to be the one really affected. There are,

however, more central inhibitions of voluntary motions which prevent active contractions temporarily, and these muscles offer the best prospects for re-educational methods.

The same may be said of the mass movement called incoordination. The muscle must be taught to resume its proper function,—first by passive motion, which brings out the proprioceptive stimuli, and then by active motion, which re-establishes and fixes the motor pattern in the brain. It is clear that only a weakened, and not a completely paralyzed, muscle can be expected to respond to such educational treatment.

DISCUSSION

The impression should not be gained that there is any kind of supremacy of the laboratory worker over the clinician. There are too many discrepancies between the situation existing in animal experiments and that obtaining at the bedside to make any laboratory results absolutely binding; on the other hand, the clinical observations are so numerous and have been made by so many competent and experienced physicians that they cannot be rejected simply because they do not harmonize with experimental findings. We cannot, however, be blind to the fact that, in many perplexing problems concerning anterior poliomyelitis, experimental medicine and basic medicine have opened our eyes to certain traditional mistakes and misconceptions which will have to be corrected or revised.

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THE DIAGNOSIS OF MENISCUS INJURIES

Some New Clinical Methods *

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INTRODUCTION

In the year 1803, William Hey of Leeds wrote of a condition which he termed "internal derangement of the knee". This was not a clear-cut entity, but it did include the first, somewhat vague, description of locking; and Hey suggested that locking might be due to a meniscus lesion. However, as he treated his patients by manipulation alone, direct confirmation was not obtainable. The literature records hardly any progress in diagnosis for almost one hundred years, but the succeeding twenty or so years contain a galaxy of great names.

First Sir Robert Jones and later D'Arcy Power, Martin, and Morison recorded the results of numerous meniscectomies, and focused attention on the longitudinal split as the primary lesion. Then, in 1924, Bristow[1] opened a discussion on internal derangement of the knee at a meeting of The British Orthopaedic Association; and since that time Bristow[2], Platt[3], McMurray, and others have described large series of cases of knee injury, with areful analyses of their findings. Despite the meticulous work in all these series, one ature stands out,—namely, the high proportion of cases in which *no* meniscus split was een at operation. Sir Robert Jones quotes a figure of 10 per cent., while Bristow found that in 30 per cent. of his cases there was no split, this proportion including many normal and hypermobile menisci.

Many attempts at an explanation have been made, but as recently as 1930 Platt was driven to conclude that this group remained an enigma. However, by this time the rotation sprain of the knee, in which the attachments of the medial meniscus to the tibia, capsule, or tibial collateral ligament were damaged, had also been described; and various authors had already emphasized the difficulty in distinguishing a rotation sprain from a split meniscus.

With all these advances, two notable gaps remain: first, the absence of any constant and reliable pathognomonic sign for a split meniscus; and, second, the difficulty of differentiating a split meniscus from a rotation sprain. The purpose of this paper is to describe some methods which aim at filling these gaps.

THE CAUSAL FORCE IN MENISCUS DAMAGE

The causal force in meniscus damage is clearly recognized. With the knee flexed and bearing weight, a twist occurs. Since the meniscus is fixed between the tibial and femoral condyles, if excessive rotation takes place, something must give way. Sometimes this grinding force splits the substance of the meniscus, and from this primary tear secondary extensions may occur, producing the different varieties of torn meniscus. Precisely the same force may, instead, wrench the meniscus away from some of its peripheral attachments, thus producing the so-called rotation sprain. It is quite true that weight-bearing (and therefore a grinding force) is essential in the production of a split in the meniscus, whereas it need not be present for a rotation sprain to occur. The important point, however, is that the selfsame force may, on occasion, produce either type of injury; and therefore the history may not help in differentiation.

* Read at the Spring Meeting of The British Orthopaedic Association, Newcastle-upon-Tyne, May 1946.

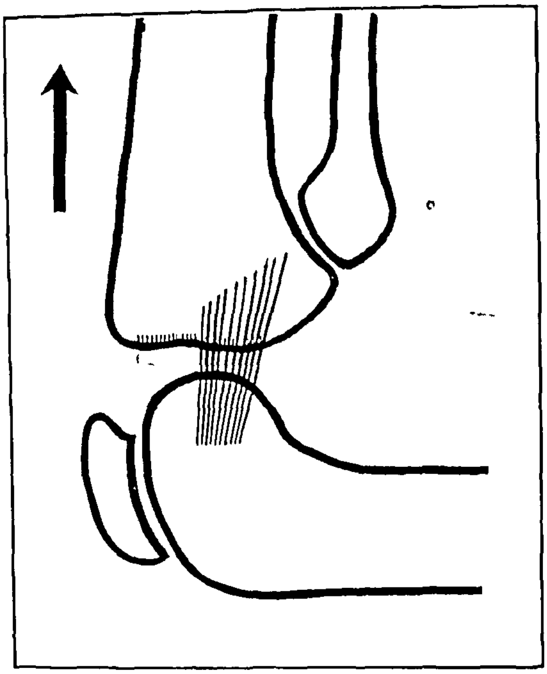

FIG. 1
Distraction of the knee.

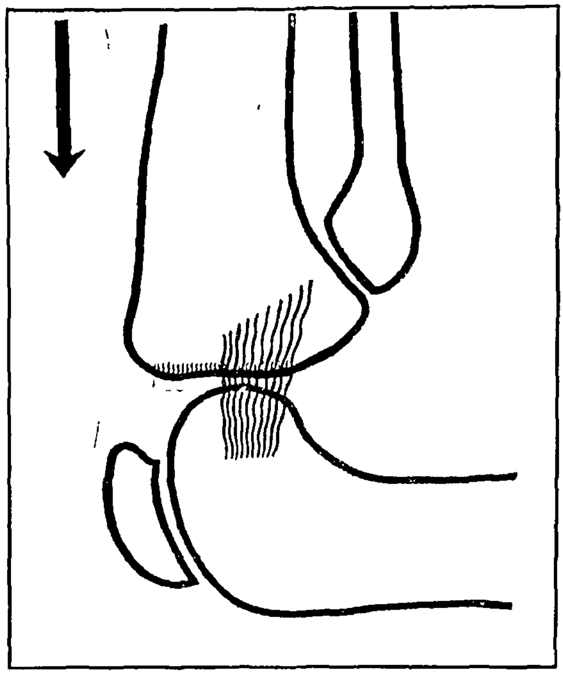

FIG. 2
Compression of the knee.

THE PRESENT METHODS OF EXAMINATION FOR MENISCUS INJURY

The most important feature in the present-day method of examination for a meniscus injury is rotation of the tibia, while the knee is held in varying degrees of flexion, as, for example, in McMurray's test. This manoeuvre is calculated to displace a meniscal fragment and to produce the well-known click, which is palpable, constant in position, and recognized by the patient. Together with the history (which, although of the highest importance, is not dealt with in this paper), a diagnosis can usually be made. All too often, however, signs are absent, and there seem to be three disadvantages in this method of examination:

1. A click is not a truly reliable sign. Its cause may lie in a different knee injury or in a different joint entirely. Many surgeons fail to find it at all, although McMurray declares that the diagnostic click is reliably constant in his personal cases.

2. The routine method of testing by rotation must necessarily pull on those tissues damaged in a rotation sprain, so producing extraneous pain. Thus, in the very process of testing for a meniscus injury, the surgeon may actively confuse the picture.

3. The third disadvantage, as Platt[9] has emphasized, is that the present method is based upon unstable mechanics. With the patient lying on his back and the surgeon examining his knee, there are two fixed points,—the pelvis, which rests on the bed, and the ankle, held in the surgeon's hand. Between these two, the long connecting levers of the thigh and the leg are unstable, and are not adequately steadied by the surgeon's hand.

A THEORETICAL SOLUTION

From the foregoing paragraphs it is evident that, in the examination of the knee, we are dealing with a confused problem of mechanics. To solve this problem, it must be resolved into its distinct components. First, stabilization of the levers can be accomplished by laying the patient on his face and fixing his femur in a way which will be described later. Second, to effect a diagnostic separation between meniscus and soft tissues, the application of a *longitudinal* stress is required. This stress should, alternately, be a separating (or distracting) force, and a compressing force; and these two types of longitudinal stress should be capable of easy application.

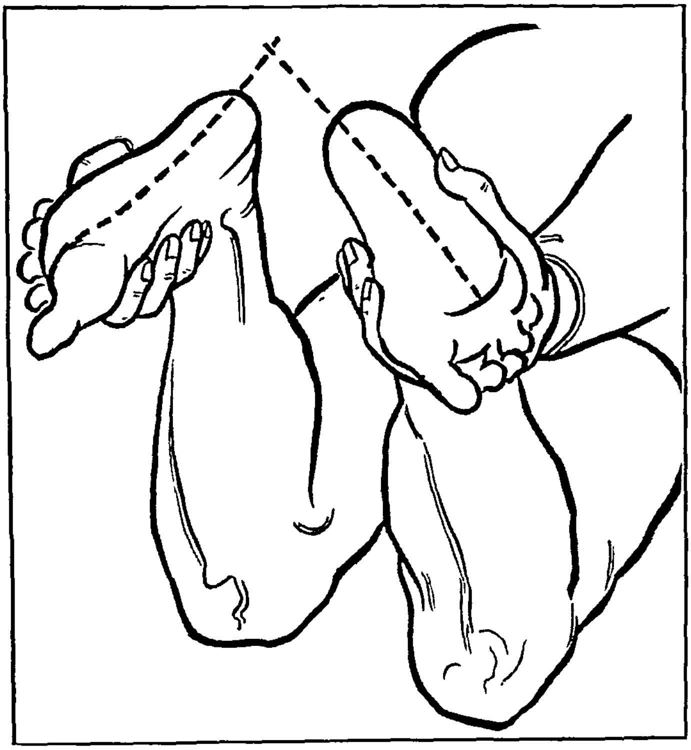

FIG. 3
Rotation of both knees—preliminary manoeuvre.

(The various illustrations epitomize both the theoretical arguments and the practical tests. These tests are easy to demonstrate in the patient, but less so in print.)

Figure 1 shows the theoretical result of applying separation or *distraction* to the knee. Clearly, the soft tissues are being stretched, while the meniscus remains undisturbed. (For simplicity, only the tibial collateral ligament is shown in the diagram, but the coronary fibers and the capsule must undergo similar stretching.) A test based on this fact is, therefore, a test of the soft tissues (ligamentous, fibrous, and capsular) and of these alone. Such a test would be positive in a rotation sprain.

Figure 2 illustrates the basis for a *compression* test. Here the soft tissues are clearly relaxed, but the meniscus itself is being crushed. In this position, in addition to the compression already produced, rotation can be added. This combination of compression and rotation constitutes a grinding force which is an accurate reproduction of the original destructive force

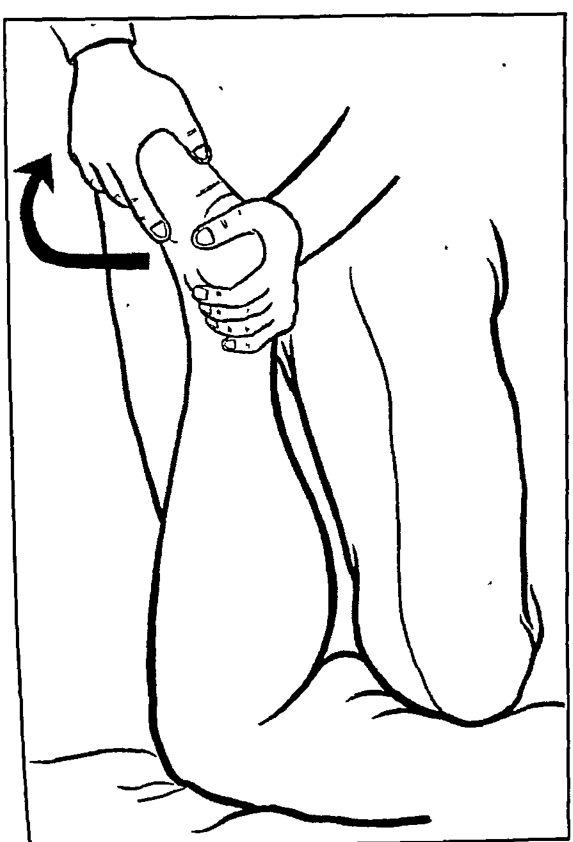

FIG. 4
Rotation alone.

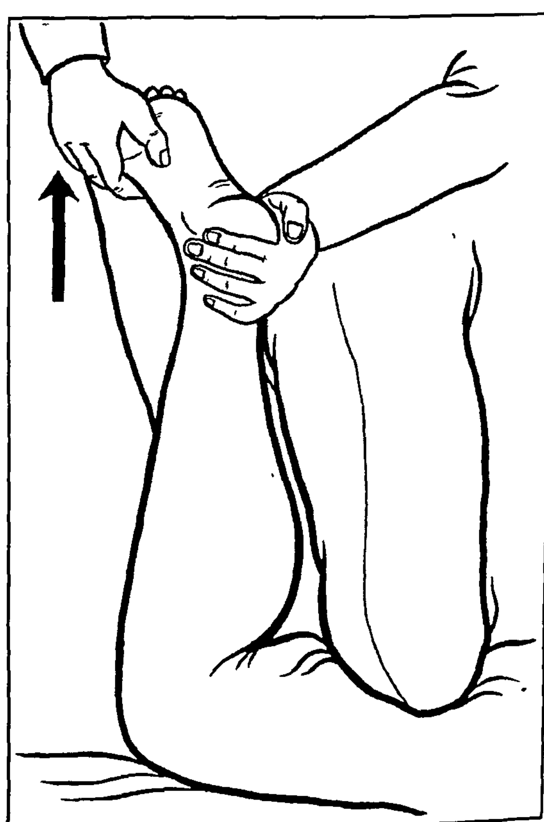

FIG. 5
The distraction test.

in meniscus damage, so that a positive *grinding* test points unequivocally to meniscus injury.

Expressed in these simple terms, the two manoeuvres of compression and distraction form the basis of the proposed tests to fulfill the requirements previously put forward. It remains to translate these theoretical considerations into practice; and, to do this, a posterior method of examination is employed.

THE POSTERIOR EXAMINATION OF THE KNEE

For this examination the patient lies on his face. He should be on a couch not more than two feet high, or the tests become difficult, and he must be well over to the edge of the couch nearest the surgeon. To start the examination, the surgeon grasps one foot in each hand, externally rotates as far as possible, and then flexes both knees together to their limit (Fig. 3). When this limit has been reached, he changes his grasp, rotates the feet inward, and extends the knees together again. This preliminary manoeuvre demonstrates limited rotation, painful rotation, and the exact angles of flexion at which these occur; the estimation of these angles proves useful later in the examination.

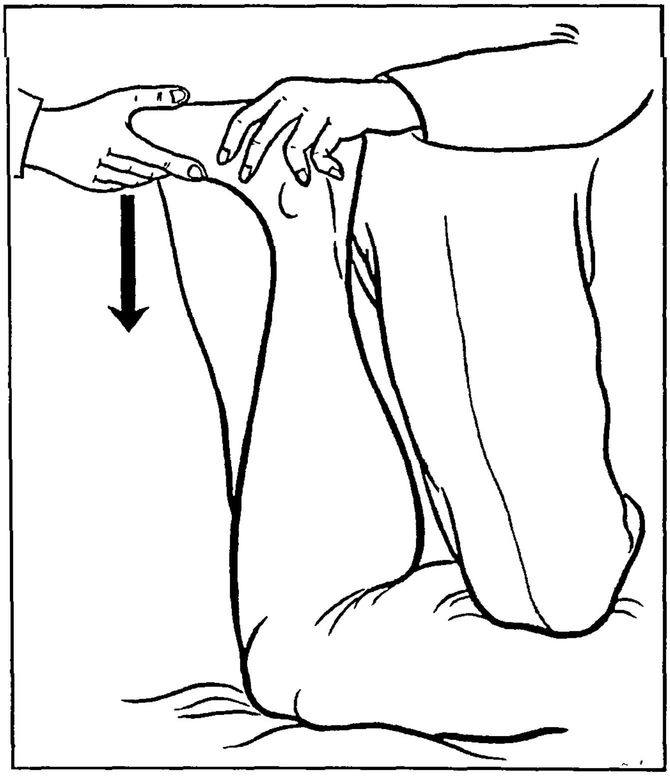

FIG. 6
The grinding test.

The surgeon then applies his left knee to the back of the patient's thigh (Fig. 4). It is important to observe that in this position his weight fixes one of the levers absolutely. The foot is grasped in both hands, the knee is bent to a right angle, and powerful external rotation is applied. This test determines whether simple rotation produces pain.

Next, without changing the position of the hands, the patient's leg is strongly pulled upward, while the surgeon's weight prevents the femur from rising off the couch (Fig. 5). In this position of distraction, the powerful external rotation is repeated. Two things can be determined: (1) whether or not the manoeuvre produces pain and (2), still more important, whether the pain is greater than in rotation alone *without* the distraction. If the pain *is* greater, the distraction test is positive, and a rotation sprain may be diagnosed.

Then the surgeon leans well over the patient and, with his whole body weight, compresses the tibia downward onto the couch (Fig. 6). Again he rotates powerfully, and again he asks two questions: (1) "Does it hurt?" (2) "How much does it hurt?" If the addition of compression has produced an increase of pain, this grinding test is positive, and meniscal damage is diagnosed.

Incidentally, this question of the amount of pain is not a matter of fine hairline distinction; the patient must be sure of a considerable difference, and indeed he usually is.

THE USES OF THESE TESTS

1. So far, attention has been focused on differentiating a meniscus injury from a rotation sprain. This is the first, and perhaps the most important, use of these tests. They

are also useful in other types of cases, however, in some of which it is necessary to introduce modifications.

2. In many patients the history lacks diagnostic precision and the common physical signs of meniscus damage cannot be elicited; the findings are vague, although the patients may be grossly disabled. Again, in many patients the diagnosis of a lesion of the posterior horn of the meniscus may be difficult. In both types of cases, surgeons are not unreasonably chary of operating in the absence of any single clear diagnostic feature in the history or the physical examination. Not infrequently, therefore, the patient limps his way, for months or years, with the aid of physiotherapy. There is, therefore, a second use for the tests; for, if the grinding test is positive, then the doubt as to the diagnosis (and incidentally the meniscus) should be removed.

With a suspected tear of the posterior horn, the grinding test is modified; instead of holding the leg at a right angle, the knee is flexed much more acutely. The importance is now apparent of determining, in the preliminary manoeuvre (Fig. 3), the angle of flexion at which pain is produced by rotation, for the test should always be repeated at precisely this angle. In this way it may be possible to obtain accurate localization of the meniscus lesion as well.

3. A third use of the tests is in the diagnosis of lesions of the lateral meniscus, which may also be difficult at times. For this purpose the tests are modified by rotating the foot inward instead of outward; in other words, a *reverse grinding* test is performed. The clue as to whether this is worth trying is again given by the preliminary manoeuvre, in which *oth* rotations at all angles of flexion were performed.

LIMITATIONS OF THE TESTS

Any diagnostic test should be judged by three fundamental criteria: (1) It should be fairly easy to do; (2) it should be constantly positive for the precise lesion concerned; and (3) it should be negative for all other lesions.

The grinding test is not too difficult, but it does need a good deal of practice and careful attention to detail. The use of a low couch, the application of considerable force in compression and rotation, and carrying out the test at the suitable angle of knee flexion are all important points, the neglect of which may result in failure.

As to whether the grinding test is always positive with a meniscus lesion and the distraction test with a soft-tissue lesion, it is perhaps too early to say. This paper is being presented at a somewhat early stage in the hope that more widespread trials will follow. Since becoming accustomed to the tests, however, the author has been surprised by their constancy.

With regard to other lesions, the author has three times found the grinding test positive when there was a pedunculated loose body other than a split meniscus. This does not seem to be a serious drawback for, quite apart from the help afforded by roentgenograms, operation was no less indicated.

RESULTS

The results by these methods are shown in Table I. The number of cases is small because, in the great majority of cases, the orthodox methods established the diagnosis simply and firmly. These cases are therefore omitted, and only fifty cases remain. Broadly speaking, Groups A and B are those in which only the application of the new tests permitted a diagnosis to be made; whereas Groups C and D, especially Group D, are those in which the tests resulted in the correction of wrong diagnoses.

Group A consists of ten cases. In none was there a history typical of meniscus injury, and in none was a single positive physical sign found by orthodox methods. In all ten, however, the grinding test was clearly positive, and in each a split meniscus was removed at operation.

TABLE I

RESULTS

Group	No. of Cases	Findings by Orthodox Methods			Findings by New Methods			Actual Diagnosis
		Typical History of Meniscus Injury	Positive Meniscus Tests	Diagnosis	Positive Grinding Test	Positive Distraction Test	Diagnosis	
A	10	0	0	No meniscus lesion	10	0	Split meniscus	Split meniscus at operation
B	13	Variable	0	Probably no meniscus lesion	13	0	Split meniscus	Split meniscus found at operation
C	15	Variable	0	? Split meniscus	0	15	Rotation sprain	Rotation sprain (not proved)
D	9	Fairly good	3	Probably a split meniscus	0	9	Rotation sprain	Rotation sprain
E	3	Miscellaneous cases for discussion						
Totals	50		3		23	24		

In the thirteen cases of *Group B,* orthodox physical examination was again negative; but the histories varied from complete vagueness to more or less definite hints of meniscus damage. Again, however, the grinding test was constantly positive; and in these cases, too, a split meniscus was removed at operation.

In a few of the cases in Group B, the history alone might possibly have led to operation. *This links up with Group C, for in the fifteen cases of this group, there was a similar* variability and vagueness in the history, coupled with absence of orthodox physical signs. To all appearances, therefore, Groups B and C are alike. In all the cases of Group C, however, the distraction test was positive, and a diagnosis of rotation sprain was therefore made.

Group D carries the argument a stage further, for it consists of nine cases in which the history definitely was suggestive of meniscus damage; moreover, in three of them a positive McMurray's sign was probably obtained. Again the grinding test was negative and the distraction test positive, and a rotation sprain was therefore diagnosed. With this diagnosis, in Groups C and D operation into the joint was not indicated. In a few cases negative air arthrograms were obtained, but the results with this method are insufficiently constant to afford proof. Purely conservative methods, including manipulation in some, appear to have justified the diagnosis. It is not unlikely that, without these tests, at least the three cases mentioned, and probably several more of this group, would have come to operation, and that normal menisci would have been removed. Here, then, are cases with an apparent diagnosis of meniscus damage, which were actually examples of rotation sprain. *It is impossible to resist the speculation that this may provide the explanation for some of those enigmatic cases in which normal menisci are removed.*

Group E consists of three miscellaneous cases. In one, the diagnosis of split meniscus was made on the basis of the history, a positive physical examination by orthodox methods, and also a positive grinding test; nevertheless a normal meniscus was removed. The remaining two cases had previously had meniscectomy; in both, a fragment of the posterior horn remained, diagnosed by the positive grinding test. They also showed a positive distraction test, however,—a curiosity explained by the presence of postoperative adhesions mimicking rotation sprain. Thus an apparent contradiction proved, *in fact, to be confirmatory evidence of the validity of these tests.*

One curious case was seen. The patient had a reasonably suggestive history and a very obvious McMurray's sign. When the grinding test was performed, and compression

and rotation were applied, there was a sudden click. Much to the patient's surprise, and somewhat to the author's, the knee was locked. To satisfy himself, the author locked and unlocked it three times in all. Fortunately this was not a very painful process; and it does seem to suggest that, in the grinding test, the correct type of force is being used.

SUMMARY

Some new tests for the diagnosis of meniscus injury, and its differentiation from rotation sprain, have been described. These tests aim at separating the individual components in knee-joint injury, and at reproducing the causal grinding force of meniscus damage. With wider experience, it is hoped that they may help to reduce the percentage of errors in the diagnosis of knee-joint injuries.

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MUSCLE FIBRODYSTROPHY

A Syndrome Causing Chronic Physical Disability

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The practice of orthopaedic surgery in the United States Army has afforded an unequalled opportunity for the examination of large numbers of young men. Deformities of the bones and joints and abnormalities of the neuromuscular system are frequently discovered by medical examining boards.

The majority of the patients examined and treated by orthopaedic surgeons have illnesses or injuries which clear up after short periods of rest, physical therapy, and general medical care. A very few have symptoms of more serious diseases or trauma, which require prolonged hospitalization and specific surgical treatment. In another group, the complaints arise from a residual disability from some injury or illness in civilian life. These latter patients are the most difficult to treat successfully in the Army. Most of them must be reclassified or discharged, under current military regulations. Among this group, members of the orthopaedic staffs of two Army Hospitals* in the Pacific Area have found an unusual number of patients with a characteristic neuromuscular syndrome, which constitutes a genuine, chronic physical disability. This condition does not seem to have been described or named previously.

Fibrodystrophy may be defined as a chronic, non-progressive muscle dystrophy, characterized by generalized weakness and contractures of all skeletal muscles. Most marked are the contractures of the erector spinae, the hamstrings, the calf muscles, and the extensors of the toes. Certain neuromuscular deficiencies of function appear as symptoms, such as poor coordination, inability to acquire skills which depend on fine muscle movements, and rapid exhaustion on physical exertion. Synonyms which could be used to describe this condition include "chronic myofibrosis", "chronic muscle contractures", "tightness of ligamentous structures", and "muscular fibrosis".

Onset of the Disease

In all of these cases the onset of the disease, when known, dated back many years. A majority of the patients were not aware of any physical handicap when they entered the Army; but, during physical training or subsequent combat duty, they found themselves lacking in physical stamina and strength. Thus the onset of symptoms and the recognition of their residual disability by most of these men occurred during the performance of duty with the Armed Forces.

Distribution of the Disease

During this study, large groups of men were examined in Army camps in Mississippi, Colorado, California, the South Pacific, the Philippine Islands, and Japan. They included soldiers from every state of the United States. In proportion to its population, no one part of the country contributed a larger number of cases of this syndrome than any other.

Incidence of the Syndrome

For this report, 264 cases of muscle fibrodystrophy have been studied and compared. These cases have been detected among approximately 12,000 patients, seen personally in orthopaedic clinics and wards of Army Hospitals during the past three and one-half years. A medical colleague, in an Evacuation Hospital in the South Pacific, has estimated that, among the 20,000 patients admitted to that Hospital in a two-year period, he had seen at

* The 31st General Hospital and 25th Evacuation Hospital.

least 200 additional cases of this condition. An incidence of 1 per cent. of the Army population is probably a conservative estimate. In a report by Kuhns, covering tightness of ligamentous structures in children, is a description of a similar condition occurring in 10 per cent. of a number of children whom he examined. It is possible that a survey of the civilian population would reveal an incidence of this syndrome of between 1 and 10 per cent.

Pathological Findings

The gross and microscopic pathology of this disease have not been fully demonstrated. In the Army, the opportunity was not given of doing a significant number of muscle biopsies. A few specimens which were examined suggest that there is an abnormal replacement of skeletal muscle fibers by connective tissue. One biopsy section was interpreted by the pathologist as "fibrosis and atrophy of skeletal muscle with fat and connective-tissue replacement". These sections were not diagnostic of a definite disease or of any single pathological process. No physiological or neuropathological investigation of the syndrome has been undertaken.

Clinical Description

The clinical picture of muscle fibrodystrophy is best illustrated by a typical patient.

A white soldier, twenty-two years old, in the fourth week of his basic training, was referred to the Orthopaedic Clinic for consultation. His chief complaint was severe pain in the muscles of his back and legs, occurring after a ten-mile hike, during which the patient carried a full infantry pack. For the three days since the march, these muscles had remained sore. The patient stated that he was unable to continue hikes or the usual morning calisthenics.

His past medical history showed no serious injuries, operations, or illnesses. At the age of sixteen he had been mildly ill for about three weeks in the summertime, with a condition which his family doctor diagnosed as "muscular rheumatism". He stated that during this sickness his muscles were "sore all over". He noticed considerable weakness when trying to walk, after getting out of bed for the first

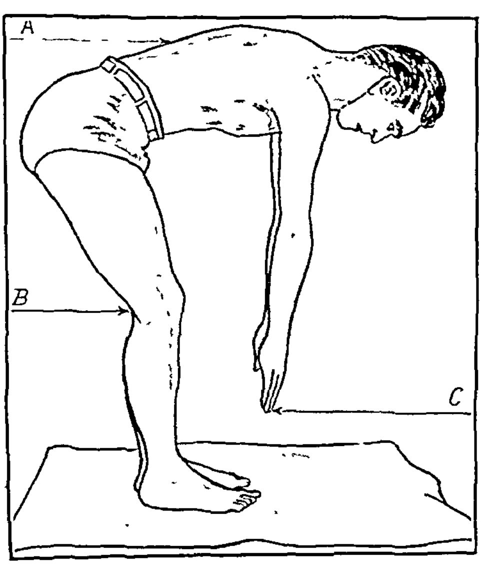


FIG. 1

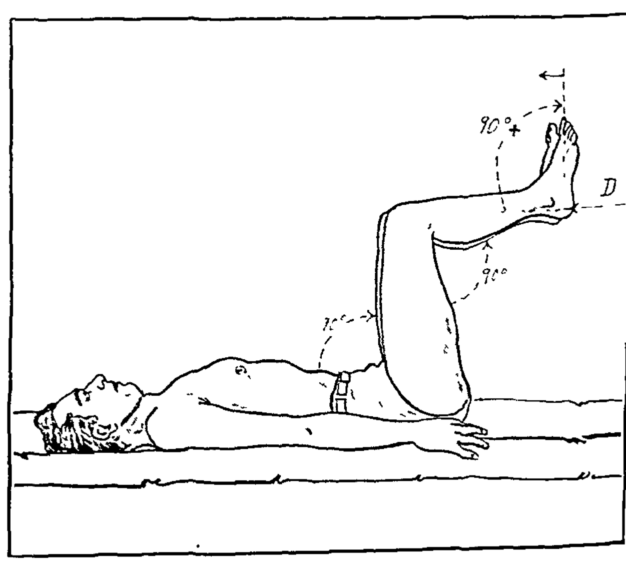


FIG. 2

Fig. 1: Contractures of erector spinae and hamstrings. Patient with fibrodystrophy is attempting the forward-bending test, trying to touch the floor with his finger tips while holding the knees straight. Note these characteristics:

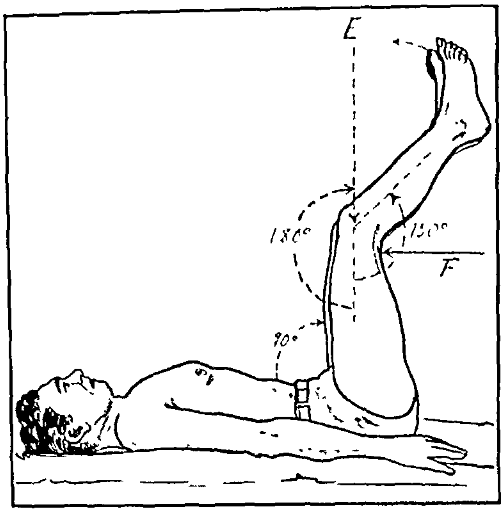
A: Lumbar spine is flattened and forward flexibility is limited, due to contracture of the sacrospinalis.

B: Hamstring tendons are prominent; knees tend to flex before patient reaches his toes, due to contractures of hamstrings.

C: At extreme of physical effort, there remains a distance of ten inches or more from finger tips to floor.

Fig. 2: Contractures of calf muscles. In the ankle-dorsiflexion test, the patient lies supine with hips and knees at right angles, trying to dorsiflex his ankles.

D: Angle of dorsiflexion in cases of contracted calf muscles is 90 degrees or greater (combined effect of contractures of the gastrocnemius, soleus, posterior tibial, and peroneal muscles).



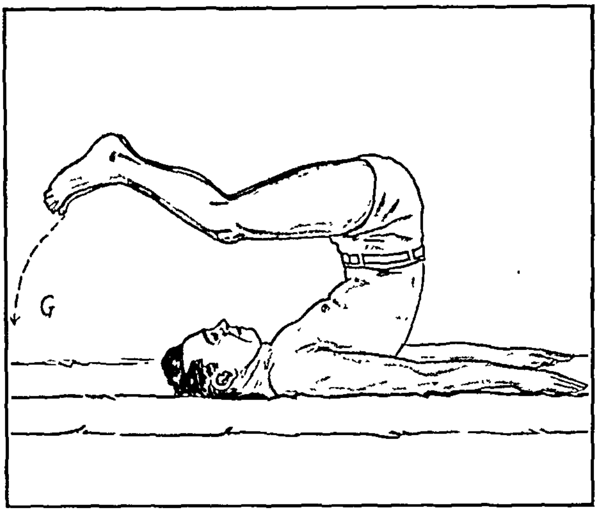


FIG. 3 FIG. 4

Fig. 3: Contractures of hamstrings. In the hamstring test, the patient lies supine with hips held at a right angle, trying to extend his knees fully.
E: Angle of extension is 150 degrees, due to contracted hamstrings (combined effect of contractures of the biceps femoris, semitendinosus, and semimembranosus).
F: Note prominence of hamstring tendons at extreme of physical effort.
Fig. 4: Contractures of thoracic muscles. In the thoracic-muscle test, the patient tries to touch his toes to the floor above his head.
G: Note inability to reach the floor with the toes, due to some degree of contracture of all dorsal body muscles.

time. Later, he believed, he was never again quite so strong as he had been. While engaged in farm work, he would tire more quickly than other men on the same job. In high school he enrolled for a course in typewriting, but after three months he had to give it up because he could not attain the speed required. In athletics he tried out for football, but in spite of being a tall and heavy boy he made only the third team. He was clumsy in passing the ball and became quite exhausted after a short scrimmage.

On induction into the Army, he passed the required examinations and was given top classification for physical fitness and suitability for combat duty. Early in basic training, he found that calisthenics were more difficult for him than for other soldiers. On forward bending, he could not touch the ground with his finger tips. His feet and legs became very tired after a few minutes of running in position. When standing at attention, he found it difficult to keep his abdomen flat. He stated that he felt like a "farmer in uniform". He made short hikes easily; but, during long hikes and marches on paved roads and parade grounds, soreness developed in the muscles of his legs and thighs, and did not disappear after a night's rest. He had no complaints concerning his other body systems, and he seemed quite desirous of completing the course of basic military training with his friends.

Physical examination showed a well-developed, well-nourished young man in apparently good health. His height was six feet, weight 175 pounds. His posture showed a moderate increase of lumbar lordosis and a prominent and relaxed abdomen. The gait was good except for eversion of the feet of about 20 degrees, due to tight calf musculature. Laterally, his spine was straight. The small toes on both feet cocked up and barely touched the floor when he was standing. Examination of the head, neck, chest, and abdomen disclosed no other abnormalities. Examination of the muscular system showed that, while his skeletal muscles appeared normal in size and contour, they seemed softer than normal and lacked normal muscle tone. In testing his joints for range of motion, it was demonstrated that the apparent limitation was not due to any abnormality of the articulations of the spine and extremities themselves; but the restriction was in the lengths to which his muscles could be stretched.

Demonstration of Muscle Contractures

1. In bending forward, while standing with knees extended, the patient's finger tips could not reach closer than ten inches from the floor (Fig. 1). In this position, flatness of the lumbar spine was noted, due to contractures of the sacrospinalis muscles, which limited forward flexibility of the lumbar joints like "checkreins". At the extreme limit of bending, his knees would flex slightly and the hamstring tendons would appear prominent, due to contractures of the muscle bodies of the hamstrings.

2. When lying on his back, dorsiflexion of the feet at the ankles was limited to 90 degrees, regardless of whether his knees were flexed or completely extended (Fig. 2). This tightness of the calf muscles appeared to be due to contractures of both the gastrocnemius and soleus. On plantar flexion of the ankles, the toes assumed a cock-up position, due to contractures of the long extensor muscles of the toes. Joints of the feet and of the toes were very flexible, and there were no bone or joint deformities.

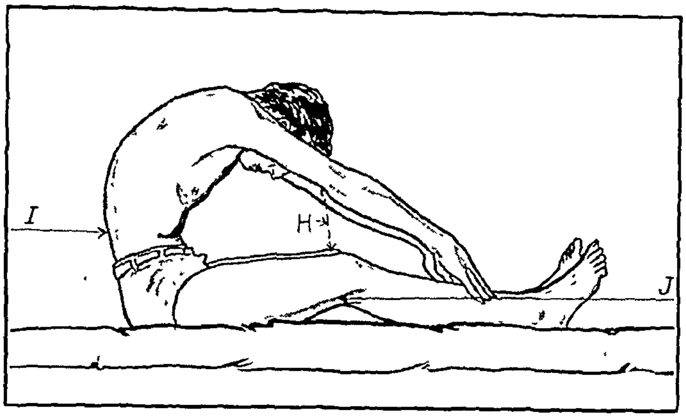


FIG. 5

Contractures of erector spinae. In the trunk-flexion test, the patient attempts to touch his head to his knees from a sitting position.

H: Note distance of ten inches or more from forehead to patellae.

I: Lumbar spine is flattened as a result of contracted sacrospinalis muscles.

J: Hamstring tendons are prominent as knees tend to flex at extreme of physical effort.

3. In attempting the straight leg-raising test, his knees could not be extended to *more than 165 degrees.* This was due to the bilateral contractures of the hamstrings (Fig. 3).

4. Contractures of all thoracic muscle groups were further shown by having the patient attempt to touch his toes to the floor above his head, while lying on his back (Fig. 4).

5. In a sitting position, bending forward, he could not bring his fingers closer than ten inches from his toes, and his knees would flex upon further effort. In trying to touch his head to his extended knees, he could not come closer than a distance of about ten inches (Fig. 5).

6. Palpation of the muscle groups in which the patient complained of pain showed that they were tender and slightly swollen at the junction of the muscular and tendinous portions. The sacrospinalis muscles were tender over their insertion on the sacrum.

The findings on neurological examination were within normal limits. All muscle and tendon reflexes were present, but slightly diminished. The Babinski and Romberg signs were absent. There was no spasticity or clonus. Temperature, pulse, respiration, and blood pressure were normal. Roentgenographic examinations of the lumbar spine and the feet showed no abnormality or congenital anomaly.

The clinical diagnosis was moderate muscle fibrodystrophy, caused by an undiagnosed illness at the age of sixteen.

CLINICAL FINDINGS

Variations in the Disease

Patients were referred to the orthopaedic consultant with a variety of symptoms and diagnoses. The clinical impression of the referring physician varied from "arthritis" and "neurosis" to "acute polyarticular rheumatism" and "malingering". "Myositis", "fibrositis", "strains" and "sprains" of muscles and joints, "tenosynovitis", and "psychoneurosis" were also frequent diagnoses. The symptoms, however, showed very few clinical variations. The patients most often stated that their symptoms had been brought on only by severe and unusual physical exertion. They complained of muscle soreness, tenderness, and pain on stretching their fatigued muscles. These symptoms were relieved by rest, heat, and massage; on return to duty—no matter how much they exercised—their muscles still remained weak and they would have recurrences of their symptoms after marches, hikes, obstacle courses, and similar training procedures.

Medical History

The medical histories of these patients are of unusual importance, as they indicate the probable etiology of this syndrome. Of the 264 patients included in this study, 112 dated their disability from some definite illness in childhood. Forty-eight of these stated that this illness was a recognized attack of "infantile paralysis" (Table I). From their own memories or from information received from other members of their families, a few could give further details. Twenty of these patients had been hospitalized for infantile paralysis and discharged as "cured", after from three weeks to six months of treatment. Twenty-eight others were treated at home by their family physicians, who in most cases had stated that the patient had fully recovered from a mild case of poliomyelitis, without residual paralysis or deformity. Sixty-four others gave a positive history of some episode in childhood which closely resembled a mild attack of poliomyelitis. These illnesses were

TABLE I

PAST MEDICAL HISTORY

	Number of Patients
Known diagnosis of poliomyelitis	48
Illness resembling poliomyelitis	64
No known causative illness	152
Total	264

variously described as "epidemic fever", "paralysis fever", "flu in the throat", "leg-muscle paralysis", "summer fever", "muscular rheumatism", "diphtheria paralysis", the "flu", and the "grippe". Several of the patients described symptoms which are common in mild attacks of poliomyelitis,—such as, a preceding infection in the upper respiratory tract, gastro-intestinal upset and vomiting, fever, sore throat, headache, and weakness in swallowing, simulating a bulbar type of poliomyelitis. Almost all described muscle pain and tenderness, stiffness of the neck, and stiffness and soreness in the muscles of the legs and back. Many stated that they were weak for several months after their illness. Some of them reported difficulty in learning to walk again, or had an unsteady gait after the illness. On questioning, those who were afflicted in their teens often knew of other cases of infantile paralysis in the same neighborhood during the summer months in which they were ill. At the time, however, they did not realize that their illness might have been a mild form of the same disease. Eight patients stated that some other members of their family had been ill the same year with a paralytic form of poliomyelitis, including residual muscle weakness and atrophy. Only nine were sure that the diagnosis of poliomyelitis had been confirmed by spinal-fluid examination. Six had been in casts or splints during the acute stage of the illness. Three patients had worn braces during the convalescent period. In one patient a stabilizing operation of the right foot had been performed.

One hundred and fifty-two patients in this series could give no definite history of any illness resembling poliomyelitis. Some of them had had severe illnesses in infancy or early childhood, in which a definite diagnosis was not remembered by the patient. In spite of the negative medical histories of the majority of these patients, there was no detectable difference in the presenting symptoms and physical findings of those who knew that they had had poliomyelitis and those who did not.

Careful comparison of the physical prowess and athletic ability of these patients indicated many deficiencies. They had never been physically strong, as compared with other boys of similar ages. They had noticed unusual fatigue and exhaustion, and previously they had attributed these symptoms to being "naturally weak" or "short of wind". If this condition had been recognized early in their lives, they had accepted it naturally and had adjusted their physical activities to their disability, without being aware of the cause or full extent of their handicap. Most of them had been in sedentary trades or occupations not requiring prolonged physical exertion. Only a few had been farmers. Most of them were students, clerks, salesmen, or office workers. In school they had not excelled in any athletic activity. If they engaged in competitive sports, they had failed to make the team. Some of them were fair in tennis, swimming, or golf, but not on a competitive level. In addition to rapid fatigue and exhaustion, they had noticed poor coordination, that they were weaker than other men, and that their muscles had not developed in size or power.

Lack of coordination and fine muscle movement was also evidenced by poor handwriting. Not a single patient had acquired the ability to play well any musical instruments which require finger coordination,—such as, the piano, stringed instruments, or reed instruments. In contrast to their physical accomplishments, they usually showed a high record of intelligence and scholastic performance in school and college. Most of them had been successful in business and social life. One fact found in every history was the lack of

TABLE II
BODY TYPES

	Number of Patients
Asthenic habitus	168
Obese	80
"Muscle-bound"	16
Total	264

progressive nature of this physical disability On this, the patients were quite definite This is a characteristic and diagnostic feature of the syndrome.

In the Army, the majority of these patients failed to complete basic infantry training Almost all of them had to be reclassified for limited duty because of muscle fibrodystrophy It seemed apparent, however, that these patients had made more than an ordinary effort to complete their physical training, even at the expenditure of unusual amounts of physical and nervous energy; and they had endured for some time considerable pain, fatigue, and discomfort.

Physical Findings

Physical examinations of these patients showed three types of body conformation and development The majority of the patients comprised a group having asthenic habitus and poor muscle development. They tended to be thin, stooped, and slightly underweight; they had increased lumbar lordosis and prominent abdomens. The patients in the second group were heavier in build and weight, but showed abnormal depositions of fat The smallest group of patients showed good muscle development, but they were markedly "muscle-bound" (Table II).

Postural and static deformities were common (Table III). The spine showed an increased thoracic curve, increased lumbar lordosis, and scoliosis, with compensated symmetrical S curves to both right and left and mild rotation. The pelvis was frequently tilted forward, but no obliquities were noted. Slight to moderate recurvatum was the most frequent deformity noted in the knees, and there were several cases of slight to moderate bowing of the tibiae. The deformity most frequently seen in the foot was cocking up of the smaller toes. Pes planus and pes cavus were found in about equal numbers; they were associated with contracted peroneal muscles or with contracted plantar fascia and short flexor muscles of the toes, respectively. About 5 per cent. of the patients showed unilateral asymmetry of the lower extremities. Slight to moderate atrophy of the thigh and calf muscles frequently was present. Occasionally there was a measurable weakness in one or

TABLE III
DEFORMITIES

	No. of Deformities	Number of Patients
No deformities		84
Mild deformities		180
Scoliosis	22	
Round shoulders	46	
Exaggerated lordosis	60	
Pelvic obliquity	0	
Unequal leg lengths	11	
Unilateral muscle atrophy	21	
Genu recurvatum	3	
Pes planus	18	
Pes cavus	33	
Cock-up of toes	26	
Miscellaneous	4	
Total	244	264

TABLE IV
MUSCLE CONTRACTURES IN 264 PATIENTS

Muscle	Number of Patients
Sacrospinalis	264
Hamstrings	264
Calf muscles	140
Plantar fascia	30
Toe extensors	23
Upper trapezius	6
Pectoral muscles	5
Psoas muscles	3
Miscellaneous	5

the other leg, chiefly in the anterior peroneal or quadriceps muscles. Several of the patients showed shortening of the weaker lower extremity of from one-half inch to an inch. No cases of weakness or atrophy of the abdominal or trunk muscles, or of the upper extremities, were noted.

The one positive physical finding common to all of these patients was contracture and shortening of the sacrospinalis and hamstring muscles (Table IV). No cases were found which had shortening in one of these groups without having contractures in the other, also. Most of the patients, however, had more extensive involvement than simply these two muscle groups. Contractures of the calf muscles, plantar fascia, extensor muscles to the toes, peronaei, tibialis posterior, hip adductors, longissimus dorsi, and pectoralis major muscles were also frequent findings. Wherever tests for poor muscle development and contractures of the spine and hamstrings were positive, a typical history of previous physical handicaps and of other symptoms of muscle fibrodystrophy, confirming this diagnosis, could be obtained. Neurological examinations of these patients showed no single typical picture. Sensory examinations and the cranial-nerve examinations were always normal, but the reflex response and the degree of muscle atrophy were extremely varied. The most common finding was that of diminished tendon reflexes, particularly in the lower extremities. Tendon reflexes were absent in a few patients. Rarely, patients were found to have hyperreflexia, with unsustained ankle or patellar clonus. The abdominal and cremasteric reflexes were normal. The Babinski sign was absent in all cases.

The laboratory findings, in the forty-two patients who were hospitalized for study, were all within normal limits. The serology was negative. The red blood counts and hemoglobin were normal. The white blood counts were not elevated. There was no eosinophilia. Urinalyses were normal. Roentgenograms of the chest were normal. Sedimentation rates were not elevated. Malaria smears from a dozen patients were negative. Lumbar punctures on eight patients showed normal cell counts and protein in the spinal fluid. There was no evidence of circulatory block or of increased pressure due to cerebrospinal fluid. Roentgenograms of the bones and joints in twenty of the patients showed one congenital anomaly of the lumbosacral joint. There were four cases of well-compensated scoliosis. Two of the patients in the hospital had enlarged and chronically infected tonsils. In several patients infected teeth required removal. The incidence of foci of infection was very small, and seemed in no way related to the patient's symptoms of muscle pain.

Differential Diagnosis

The findings in the 264 patients in this series diagnosed as having muscle fibrodystrophy resemble most closely the clinical picture of patients who have recovered from paralytic attacks of acute anterior poliomyelitis. However, generalized muscle contractures are the main features of fibrodystrophy. In paralytic poliomyelitis, the most notable features are the weakness and muscle atrophy which usually follow the paralysis.

Pathological types of muscle contracture are uncommon in the medical literature. Kuhns has reported a congenital type of muscle contracture which he designates as "tight-

ness of ligamentous structures". He found this condition in approximately 10 per cent. of the children examined. Easy fatigability and pain in the back after hard playing were common findings. A familial incidence was present in more than one-half of the cases, and minor developmental deformities of the lower part of the back were found by roentgenographic examination in one-quarter of his patients. Kuhns believes that the contracture is congenital in origin, but there may be acquired forms as a result of prolonged fixation in bed, casts and braces, and vitamin-C deficiency.

The possibility that these cases of fibrodystrophy might represent some form of myositis or chronic infectious myopathy has been considered. At the time of examination, none of the patients showed evidence of any acute or chronic inflammatory or infectious disease. In the involved muscles there was no sign of local inflammation or tender nodules, such as are usually found in myositis or fibrositis. Fibrodystrophy can be differentiated from rheumatism and rheumatoid arthritis by the normal sedimentation rate and the complete absence of joint phenomena, periarticular swelling and tenderness, and arthritic involvement of the joint surfaces. Roentgenographic studies of the joints in fibrodystrophy disclose no pathological changes which are characteristic of, or can be associated with, the disease process.

Chronic intramuscular fibrositis in the residual stages, as described by Slocumb, resembles somewhat the picture of muscle fibrodystrophy. In intramuscular fibrositis, however, an active disease process is present; and the symptoms are worse after periods of inactivity than after exertion, as in fibrodystrophy. Patients with intramuscular fibrositis have definite stiffness in the morning and aching pains related to changes of temperature and humidity. The patients reported here had mildly aggravated symptoms in cold weather, but they noticed no increase in fatigue or muscle pains due to dampness, and morning stiffness was not a characteristic symptom.

The myopathies and the hereditary and familial diseases of the neuromuscular system have been ruled out in the differential diagnosis of muscle fibrodystrophy. This syndrome is not progressive in character; the onset may occur at any period during infancy or childhood; spasticity and hypertrophy of the muscle bodies are completely absent; abnormal reflexes are not present; and there is complete freedom of involvement of the cranial nerves and of the functions of the cerebrum and cerebellum.

Other chronic diseases of the neuromuscular system have been ruled out by similar comparisons. In chronic degenerative myelitis, sensory abnormalities are always present; and a loss of sphincter control usually occurs in the advanced stages. In combined and multiple sclerosis there are characteristic disturbances of gait; Babinski and Romberg signs are present; and there is definite spasticity of the muscles and extremities.

Prognosis

A number of these patients were followed for as long as three years in the Military Service. During this time, none of them showed any progression in the signs and symptoms of the disease. Some, who had been aware of their physical disabilities for ten years or more, stated that they had noticed no increase in muscle weakness, stiffness, or other changes, which could not be attributed to their advancing age. Since this syndrome is a residual physical disability, rather than an active disease process, the prognosis for these patients is excellent.

TREATMENT

In this series of patients, treatment was necessarily limited to their presenting symptoms. These were, in order of frequency, pain in the muscles of the back and legs, tenderness in the muscles on stretching of the musculotendinous junction, exhaustion and fatigue, and a feeling of muscle weakness and loss of strength. The mild cases were

treated by physical therapy,—principally infra-red rays and massage; aspirin was given for its analgesic action; and a request was sent to the patient's military unit, recommending assignment to light duty for a period of from five to ten days, or until the muscle symptoms disappeared. In the more severe cases, the men were admitted to the hospital, where they were put on the regimen of bed rest and intensive physical therapy,—principally whirlpool baths, followed by massage, and active exercises for improving posture and strengthening individual muscle groups. These patients were usually treated for from one to three weeks. Those in whom the syndrome seemed so pronounced as to interfere with their military duties were recommended for reassignment to other units, or to jobs in the same unit which did not require so much marching, lifting, or carrying of heavy packs. A total of seventy-two patients were reassigned to limited service. No patient had to be separated from the Army because of this condition.

PSYCHOLOGICAL FACTORS

As with the majority of patients in the Military Service, attention had to be given to the mental aspects of this condition,—as regards both symptoms and treatment. A large number were referred to the orthopaedic clinics from the Neuropsychiatric Section of the Medical Service, where they had been admitted for study and observation. Some had already been given various neurological or psychiatric diagnoses. "Neurasthenia", "effort syndrome", "unclassified psychoneurosis", "hysteria", "anxiety state", "suspected malingering", and "constitutional psychopathology" were the most frequent functional diagnoses applied to this syndrome. There was justification for the development of a mild psychoneurosis in some of these patients. They became aware that they had a disease condition which produced definite symptoms, but in the diagnosis of which the doctors could not concur, explain in terms which the patient could understand, or treat so that the symptoms would not return. When first examined, many patients were tense, nervous, worried about their physical state, apprehensive about the possible progress of the disorder, and resentful of the fact they were considered "mental patients", when the symptoms in the beginning had been only in their muscles. The best psychological treatment was to explain to the patient in simple terms the true cause and nature of his disability. With the more intelligent patient, the examiner would point out that the condition was not a "disease", but was merely the result of an infection in childhood,—probably a mild attack of poliomyelitis. The patient would be reassured that it was not serious, not progressive, and not in any way a threat to future health and earning power upon return to civilian life. It was demonstrated that the symptoms could be relieved by short periods of physical therapy, and that they could be avoided by keeping physical exertions within the limits of strength and endurance. Exercises were recommended and sports were suggested in which the patient would not be so apt to strain himself,—that is, swimming, horseback riding, golf, and daily calisthenics. These patients were encouraged to build up their general physical strength and endurance by regular periods of active exercise; but they were advised to rest before their symptoms became noticeable. The less intelligent soldier was told that his symptoms were due to the fact that he was "muscle-bound". He was assured that it was not a serious condition; that it would never be any worse; and that, by being careful not to overexert himself, he could lead an active life without recurrence of his symptoms.

The results from treatment—both physical therapy and this type of psychotherapy—were excellent. In fact, the effects of treatment were so good as to constitute a valuable differential test between this syndrome and the purely psychoneurotic disorders. The patients with muscle fibrodystrophy responded rapidly and completely to treatment; they noticed definite improvement with each day of physical therapy; and in from one to three weeks they were ready to return to duty. The psychoneurotic patients, on the other hand, were usually relieved only temporarily, or not at all, by physical therapy. Moreover, when a

psychoneurotic patient was ordered "to duty", it was very common to note an acute "recurrence" of all his previous symptoms.

ETIOLOGY

In the medical histories of this series of patients, there was such a high incidence of acute anterior poliomyelitis that the author has concluded that poliomyelitis is the most important cause of this syndrome. A careful comparison of cases in which there was no definite history of poliomyelitis showed that the symptoms and physical findings were identical with those of patients who had a positive history of poliomyelitis. This suggests the hypothesis that acute anterior poliomyelitis is the *only* cause of muscle fibrodystrophy.

This theory is supported by the observations of other workers, reported within the past few years, on the high incidence of non-paralytic forms of poliomyelitis. Sherman, in a review of the medical literature and a report of seventy cases, has emphasized that only 10 per cent. of her patients with acute anterior poliomyelitis had sufficient residual weakness to require braces or future surgery; 8.6 per cent. had functional weakness, which did not require further therapy and was not a handicap to normal life; and 72.8 per cent. either had no residual weakness or such slight weakness that it was barely detectable (8.6 per cent. of the patients died). However, her patients were not followed for a sufficient length of time to determine the incidence of deformities or muscle contractures which developed during the growth period.

Swartout and Frank, by using the presence of muscle spasms as a new criterion for the diagnosis of acute anterior poliomyelitis by mild physical findings, were able to detect multiple familial cases of poliomyelitis which would otherwise not have been diagnosed. They reported twenty-nine families with multiple cases of infantile paralysis, many of them so mild that, if it had not been for at least one severe case in the family, the other cases would not have been correctly diagnosed. They further state: "The lack of recognition of these mild cases may account in some measure for the difference between the large number of adults who have protective substances in their blood against poliomyelitis virus and the comparatively small number who have a history of having had the disease. Unrecognized, and therefore untreated, one-sided spasm may account for the frequent orthopaedic problems of unexplained scoliosis and leg shortening."

Electromyographic studies by many workers within recent years have demonstrated that muscle spasm in acute anterior poliomyelitis is a more extensive symptom than muscle weakness and paralysis. It is inevitably present in the muscles of the lumbar spine and the hamstrings, and frequently it is present in the muscles of the upper and lower extremities. Schwartz, Bouman, and Smith have emphasized that spasticity is a general phenomenon in the early stages of infantile paralysis. By their studies, they have emphasized the general systemic effect of this disease on the muscle system.

Nielsen, in 1944, reported four cases of a generalized subacute exhaustion syndrome of the neuromuscular system, which the author believes could have been due to atypical attacks of acute anterior poliomyelitis in adults who were physically exhausted at the time of onset. His cases differ from these considered here in that their onset was in adult life and was associated with considerable muscle atrophy.

Many patients have been examined by the author, who showed some degree of muscle spasm resulting from diseases other than infantile paralysis, but it is significant that in none of them did muscle contractures or fibrosis develop subsequently. Six patients with encephalitis in an overseas Army Hospital all had, temporarily, stiff necks and spasm of the spine muscles during the acute course of the disease. Over one hundred cases of meningococcal meningitis were seen in an epidemic in an Army camp in this country. Transient muscle spasm was found in the neck, spine, and hamstrings, and frequently in the hip and shoulder muscles. Temporary atrophy was the rule with these patients, yet no permanent muscle contractures or fibrosis was seen after a follow-up of three months.

More or less involvement by muscle spasm, during some stage of the acute attack, occurs in rheumatism, rheumatoid arthritis, myofibrositis, and infectious polyneuritis. Periarticular fibrositis, with limitation of joint motion, occurs in rheumatoid arthritis; but this is quite different from the limitation of joint motion after poliomyelitis. In poliomyelitis the limitation is due to muscle spasm, and finally to interstitial fibrosis in the muscle body. The joints themselves and the joint capsules are seldom involved, and they more frequently show relaxation and hypermobility than contractures and fibrosis.

New information on the extent and the contagious nature of poliomyelitis in children has been reported by Casey and his co-workers. They found that poliomyelitis was contagious in about 90 per cent. of children from one and one-half to three and one-half years of age. Multiple cases of poliomyelitis in one family were the rule rather than the exception, when there were other children from one and one-half to eight and one-half years of age in the same home. These authors investigated the immediate family and the neighborhood of seven paralytic cases of poliomyelitis. Of sixty-six persons in contact with these seven during the infectious period, illnesses which were compatible with poliomyelitis developed in thirty-seven, within six to fifteen days; and twenty-four persons were definitely considered to have poliomyelitis. This is a ratio of infectivity of sixty-one to sixty-six. In two control groups among 224 persons who were not in contact with poliomyelitic patients, illnesses compatible with poliomyelitis developed in only nine, and not one was a significant clinical case. This is further proof that the number of persons infected with poliomyelitis among the general population is much greater than clinicians have previously realized. It is the author's opinion that, among this large group of patients with mild, abortive, non-diagnosed, and non-paralytic forms of acute anterior poliomyelitis, the clinical syndrome of muscle fibrodystrophy develops in an unknown number, with subsequent lifelong physical disability and occupational handicaps.

Smith and her associates, in a study of the origin of an epidemic of poliomyelitis in Buffalo, have demonstrated that, preceding an epidemic of recognized cases of poliomyelitis with paralysis, there are in the community many minor illnesses which are non-paralytic forms of the disease. These are often not recognized by the patients, their families, or their physicians as poliomyelitis until the paralytic cases begin to appear. These investigators have estimated that the incidence of illnesses in the community, which were highly suggestive of being non-paralytic forms of the disease, was at least five times the number of recognized poliomyelitis cases. All gradations of symptoms and of severity were encountered, and as late as one year after the epidemic some patients had signs and symptoms—such as a degree of residual weakness, atrophy of one leg, and other deformities—which finally confirmed diagnoses of poliomyelitis in what otherwise seemed to be mild illnesses.

SUMMARY

Fibrodystrophy is the proposed name for a neuromuscular syndrome, found in a series of 264 patients from the United States Army. It was originally discovered as a cause for soldiers' complaints of excessive pain and fatigue in their muscles after moderate physical exertion.

Patients with this condition are characteristically lacking in athletic ability. They have great difficulty in acquiring skill in occupations requiring fine muscle coordination,—such as typewriting, playing musical instruments, and in rifle marksmanship.

Physical examinations show three body types,—"asthenic", "obese", and "muscle-bound". Five simple muscle tests demonstrate the common findings,—contractures of the dorsal musculature of the body, particularly of the erector spinae, the hamstrings, and the calf muscle groups. Mild deformities—such as scoliosis, pes planus, and dorsiflexion of the interphalangeal joints of the toes—are frequently found, along with moderate muscle weakness and occasional atrophy.

The syndrome is a cause of lifelong physical disability, but it does not seem to be progressive after the adolescent growth period. Individuals thus affected, on entering military service, frequently for the first time became aware of their poor muscle development, impaired coordination, and lack of physical endurance.

The etiology of fibrodystrophy is presumed to be abortive or non-paralytic attacks of acute anterior poliomyelitis during the patient's infancy or childhood. A significant number of patients in this series either had a recognized case of poliomyelitis in their youth or some illness clinically similar to the milder forms of this disease. The muscle contractures which are the outstanding clinical and diagnostic features of the syndrome, are considered to be the residual pathological changes of interstitial muscle fibrosis and atrophy, following the untreated muscle spasm of the acute illness.

Treatment of this condition, consisting of rest and physical therapy, is successful in relieving the patients' symptoms of muscle pain and tenderness. For the permanent pathological changes in the muscles, no specific treatment is known. The soldiers in this series were reclassified for "limited service" and duty not requiring prolonged physical exertion.

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PSEUDARTHROSIS OF THE LONG BONES

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Non-union of fractures is not a new subject. However, it is easy to associate the occurrence of fractures to some extent with modern living, in which serious injuries frequently occur in civil as well as in military life. It is perhaps more appropriate to relate non-union to some of the newer ideas concerning the treatment of fractures. Many surgeons of the past century, like Malgaigne and Bardenheuer, never saw pseudarthrosis in closed fractures of the shafts of the bones, because they reduced the fractures accurately and kept the bones immobilized long enough to secure healing.

In accordance with Bruns's statistics, quoted by Böhler, pseudarthrosis occurs once in 200 or 250 cases, or in 0.5 per cent. of all diaphyseal fractures; according to Scudder, it occurs in from 2 to 3 per cent.; and according to Hey Groves, in from 4 to 5 per cent. Bado, in his thesis in 1941, says that pseudarthrosis is a very rare condition; and, for its occurrence, it is necessary that a strong and persistent foreign factor, opposed to the natural tendency of bone healing, be present. This factor, according to Bado, is almost always an incorrect method of treatment. Watson-Jones considers that: "Non-union of fractures is due to the failure of surgeons much more than to the failure of osteoblasts". Of course, pseudarthrosis is not a disease. It is normal for a fractured bone to heal, and non-union can almost always be avoided. In a series of 800 consecutive fractures of the shaft of the femur or tibia recently investigated by Watson-Jones, all types of treatment were used. A high percentage of these fractures were comminuted, contaminated, and severely infected. Because good orthopaedic methods were used, there was not one case of non-union in the entire series, although many fractures were slow in uniting. Ottolenghi from Buenos Aires, in a series of 172 fractures of the shaft of the humerus, reports only thirteen cases of non-union; and specifies that, of these cases, twelve were treated elsewhere, indicating that he had only one case of non-union in the series. Open reduction was used only eight times.

The present paper is based upon work done at the Orthopaedic Department of the State University Hospitals, Iowa City. Since most of the original fractures were treated elsewhere, it is not possible to give percentages of non-union in relation to the number of fractures treated. It is possible, however, to be analytical, and to review and institute

TABLE I

DISTRIBUTION OF CASES

Bones	Females		Males		Total	
	No. of Cases	Per Cent.	No. of Cases	Per Cent.	No. of Cases	Per Cent.
Femur	3	2.2	18	13.4	21	15.6
Tibia	16	11.9	32	23.7	48	35.6
Tibia and fibula	2	1.5	4	2.9	6	4.4
Humerus	12	8.9	6	4.5	18	13.4
Radius	1	0.7	6	4.5	7	5.2
Ulna	1	0.7	7	5.2	8	5.9
Radius and ulna	3	2.2	19	14.0	22	16.2
Clavicle	3	2.2	2	1.5	5	3.7
Totals	41	30.3	94	69.7	135	100.0

* Service of Arthur Steindler, M.D.

TABLE II

DEVELOPMENT OF PSEUDARTHROSIS

Ages (*Years*)	Number of Cases	Per Cent.
5 to 10	5	3.7
11 to 20	16	11.9
21 to 30	26	19.3
31 to 40	25	18.5
41 to 50	25	18.5
51 to 60	15	11.1
61 to 70	18	13.3
Over 70	5	3.7
Totals	135	100.0

details of treatment which might decrease the incidence of this disconcerting complicatioi Of 346 cases of pseudarthrosis seen in this Department from 1935 to 1945, 391 bones wer involved. One hundred and thirty-five cases of non-union involving the long bones wer selected, excluding cases of pseudarthrosis of the femoral neck, which alone numbered 12ε The 135 cases mentioned form the basis of the present paper. Attention was focused onl on cases which had the characteristic signs of non-union, clinically or roentgenographi cally,—namely, motion *in situ* or sclerosis of the bone ends. In accordance with thes criteria, some cases should have been included which had motion at the fracture site, bu they were thought to be merely cases of delayed union. It was believed that in these case the bones would heal if immobilized long enough, and consolidation did occur in many o the cases handled in this manner. They are not included in this paper.

Table I indicates the distribution of cases according to sex and location. These figure cannot be used as a criterion for the frequency and distribution in the general population but only as an indication of the frequency in the present series. The author feels that these ratios are related to the activities and occupations of the two groups.

The ages at which pseudarthrosis developed in this series are shown in Table II. The youngest patient was five years old and the oldest was eighty-four.

The relationship between the pseudarthrosis and the type of fracture was analyzed. Table III points out the number of compound and simple fractures in which non-union developed. The frequency of occurrence of non-union in simple fractures may be explained by the fact that the number of simple fractures far exceeds that of compound fractures, and also that generally the treatment of the simple fractures was more neglected.

TABLE III

OCCURRENCE OF NON-UNION

Bones	Compound Fractures		Simple Fractures	
	No. of Cases	Per Cent.	No. of Cases	Per Cent.
Femur	8	5.9	13	9 6
Tibia and fibula	27	20.0	27	20 0
Humerus	5	3.7	13	9.6
Radius	0	0	7	5.3
Ulna	3	2.2	5	3.7
Radius and ulna	8	5.9	14	10.4
Clavicle	0	0	5	3.7
Totals	51	37.7	84	62.3

The causes of non-union, as reported by many authors, are the following: (1) gross separation of the fragments; (2) interposition of soft tissues; (3) improper immobilization; (4) damage of the nutrient artery; (5) inadequacy of blood minerals, like calcium and phosphorus, or deficiency of vitamins C and D; and (6) pathological conditions of the bone, such as carcinoma or Paget's disease. In the light of present knowledge, it is practically impossible to consider one factor alone as the cause of non-union. It is evident that in some cases there is inadequate consolidation, but the etiology of this abnormality is difficult to ascertain. However, the surgeon can aid consolidation by (1) efficient apposition of the fragments, (2) adequate and uninterrupted immobilization, (3) prolonged immobilization, and (4) the avoidance of repeated attempts at reduction. Some features of this subject are surprising and inexplicable. For instance, we see many robust, healthy individuals with fractures which would be expected to heal without incident; yet pseudarthrosis is obtained. On the other hand, we see cases of osteogenesis imperfecta with multiple fractures which heal well. Steindler quotes Muscatello and Damarchelli, who in 1899 found that, even after section of the peripheral nerves, there was no disturbance in the formation of callus, and consolidation occurred without complication.

Inadequate circulation is often mentioned in the literature as a major factor in the production of non-union. It is easy to understand that an inadequate supply of blood can be of paramount importance in the healing of fractures of the femoral neck or of the carpal navicular; but the explanation is not so clear in fractures of the shafts of the long bones, since the circulation is assured by the rich blood supply of (1) the nutrient artery, (2) the periosteal arteries of the shaft, and (3) the periosteal arteries of the epiphysis. The nutrient artery divides in the marrow into two branches, one going upward and one downward. The main branch of the nutrient artery follows the direction of the nutrient foramen; and it will course distally in the humerus, proximally in the femur, and so forth. Both branches of the nutrient artery give off smaller branches for the nutrition of the marrow and those which penetrate the haversian canals and then anastomose with the arterial ramifications which come from the periosteal arteries. When the branches of the nutrient artery terminate in the epiphysis, they anastomose with the ramifications that the epiphysis receives from the periosteum. The periosteal arteries of the shaft arise from the periosteum. They are present in large numbers and penetrate the bone through third-order foramina as capillaries within the haversian system, anastomosing as already described. The periosteal arteries of the epiphyses originate from the periosteal layer which lines the epiphysis, and penetrate through second-order and third-order foramina. This would indicate that the three systems of arteries having such good anastomoses provide adequate circulation for bone nutrition, even in cases where there might be some interruption of any of these systems.

In Table IV are recorded the locations of the fractures of the long bones. Of the 135

TABLE IV

LOCATIONS OF FRACTURES OF THE LONG BONES

Bone	Total Number	Upper Third		Junction of Upper and Middle Thirds		Middle Third		Junction of Middle and Lower Thirds		Lower Third	
		No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Femur	21	6	28.6	0	0	9	42.8	3	14.3	3	14.3
Tibia	54	11	20.4	4	7.4	17	31.4	11	20.4	11	20.4
Humerus	18	2	11.1	1	5.5	5	27.8	3	16.7	7	38.9
Ulna	24	4	16.7	4	16.7	0	0	12	50.0	4	16.7
Radius	25	2	8.0	1	4.0	12	48.0	5	20.0	5	20.0
Totals	142	25		10		43		34		30	

TABLE VIII

MASSIVE ONLAY GRAFT SECURED WITH CHROMIC CATGUT

Bones	Number of Cases	Results	
		Good	Poor
Humerus	3	0	3
Tibia	1	0	1
Radius and ulna	1	0	1
Ulna	3	1	2
Totals	8	1	7 (87.5%)

strated experimentally that the periosteum contributed little in the formation of new bone. In dogs, where the periosteum was removed from the graft, a fibrous periosteum developed in the surrounding connective tissue. This fibrous periosteum, in four out of five dogs, showed evidence of a more cellular development and more formation of young bone tha occurred in those in which the periosteum had not been removed. Clay Ray Murray state that: "New bone will form in the normal adult human tissues only in undifferentiate connective tissue in the presence of available and sufficiently locally concentrated calciur and, possibly still more important, phosphate, and in a medium having a pH not too fa to the acid side. . . . In bone grafting, our problem, then, resolves itself into placing readily vascularizable calcium structure in a freshly prepared rich capillary bed, . . eliminating movement between the graft and the bone host, and maintaining optimun efficiency in the local minute circulation during the period of incorporation of the graf with the host." Using these principles in the surgical procedures, Murray advises:

1. Preoperatively: To improve the condition of atrophic bones and poor muscles; t eat scars or other skin conditions; and to eliminate infection.
2. Operatively: To have tissues of good viability *in situ.*
3. Postoperatively: Perfect immobilization.

In this paper, it is not intended to go deeply into the surgical technique, since all th details have already been described in the extensive literature on the subject. It is sufficien to mention that practically the only two methods used today are the inlay type of bon graft, used especially by Albee and his followers, and the massive onlay grafts. The inlay or countersunk, graft came into general use about 1912, and for many years was the metho of choice. In 1927 and 1928, Campbell in Memphis, Tennessee, and Henderson in Rochester, Minnesota, developed the method of massive onlay grafts. In 1936, Henderson said: "Experience has taught us that the larger the graft, the better the chances of success". He called his graft the "massive graft", whereas Campbell called it an "onlay graft". It might be more appropriately designated a "massive autogenous onlay graft".

Some changes have been made in the original technique, the principal one being the combined use of massive onlay grafts and vitallium screws to accomplish good internal

TABLE IX

INLAY BONE GRAFT FIXED WITH CHROMIC CATGUT

Bones	Number of Cases	Results	
		Good	Poor
Femur	3	3	0
Tibia	10	5	5
Radius and ulna	6	3	3
Radius	1	0	1
Humerus	1	1	0
Totals	21	12 (57.1%)	9 (42.9%)

TABLE X

INTERVAL BETWEEN INJURY AND TREATMENT

Time Interval	Number of Cases
Less than 6 months	8
6 months to 1 year	38
1 to 2 years	17
2 to 3 years	10
More than 3 years	11
Total	84

fixation. The reports of this technique by Campbell and Boyd in the United States and by Meekison in Canada are sufficiently clear and detailed so that further description is not necessary.

Methods and Techniques

On the 135 cases of non-union in this study, 106 surgical procedures were performed. Tables VI, VII, VIII, and IX show the results of onlay grafts with various modifications. Good results are those with solid union and poor results are those with persistent non-union. In one case of non-union of the radius, a massive onlay graft was used with a plate and vitallium screws. Solid union occurred, but infection was present. In five cases of non-union of the tibia, the use of massive onlay grafts with vitallium screws was combined with inlay grafts. The results were good in three cases; non-union persisted in the other two cases.

These figures indicate that much better results were obtained with grafts secured with vitallium screws, and imply that the important factor is adequate immobilization of the graft.

For more than twenty years, Campbell has been using bone pegs to secure bone grafts. Lately the results with vitallium screws, used to fix the grafts, have been so gratifying that the use of bone pegs has been practically abandoned. The vitallium screws provide better mechanical fixation and simplification of technique. Campbell and Boyd report 93.2 per cent of good results and 6.8 per cent. of unsuccessful ones. In Table VII are noted the results obtained with massive dual onlay bone grafts. These surpass the results obtained by other methods. The results are more significant, since the success with this procedure was obtained in cases where other surgical bone-grafting procedures had failed. The results with one or two massive onlay bone grafts (88.2 per cent. and 87.5 per cent. of good results) give a clear idea of the value of the method, when compared with the 87.5 per cent. of poor results obtained when the graft was fixed with chromic catgut.

The inlay method of Albee is characterized by precision and accuracy in fitting the graft into a prepared bed. The results in this series with inlay bone grafts are shown in Table IX. In seven fractures of the tibia, sliding inlay grafts were fixed with chromic catgut. The results were good in five cases and poor in two. In one case, an inlay bone graft fixed with bone pegs also resulted in failure. Of two cases of pseudarthrosis of the

TABLE XI

POSTOPERATIVE INFECTIONS IN 135 CASES

Bones	Number of Cases	Previous Infection	No Previous Infection	Previous Open Reduction	Previous Compound Fracture
Tibia	5	1	4	3	2
Humerus	1	1	0	1	0
Radius and ulna	3	1	2	2	2
Totals	9 (6.6%)	3 (2.2%)	6 (4.4%)	6 (4.4%)	4 (3.0%)

TABLE XII

Follow-Up After Operation

Time	Number of Cases
6 months to 1 year	18
1 to 2 years	29
2 to 3 years	12
More than 3 years	25
Total	84

tibia treated with inlay bone grafts fixed with vitallium screws, one resulted in good union and one in failure. Another case of non-union of the tibia was treated with an inlay sliding bone graft and held with a vitallium screw; this resulted in solid union. Finally, three cases of non-union of the ulna, treated with inlay and onlay bone grafts fixed with chromic catgut, resulted in two failures and one case of solid union.

A consideration of the various techniques shows that the results with massive onlay bone grafts fixed with vitallium screws are obviously more favorable. Another significant point is that, when dealing with an easily exposed bone, like the tibia, the inlay procedure is relatively simple. However, when grafting the small bones or the deeply placed femur, it is a much more difficult problem.

During surgery, it is the policy in this Department to resect the sclerosed bone ends until a good bleeding end is obtained and then, by drilling, to open up the marrow cavity. Occasionally it is necessary to resect a few inches of the affected bone, which results in a shorter limb. It is therefore important to inform the patient, before operation, that his xtremity may be shorter than it was before.

The interval between injury and treatment varied from two months to more than three years (Table X); one patient had a pseudarthrosis for more than ten years. Relatively few patients are operated upon within six months of the time of injury. This arbitrary time limit gives the bones the maximum chance for healing before surgical intervention is attempted.

In cases where suppuration was present, no bone-grafting was tried until there had been complete cessation of infection for at least six months. In only one case was grafting attempted within six months, but union was obtained. In nine cases suppurative processes were present after surgery (Table XI), but healing was finally obtained in five of them. The incidence of postoperative infection was 6.6 per cent. Henderson gives an incidence of postoperative infection in similar cases of 18 per cent.[9]

In this Clinic, local sulfonamide therapy is seldom used; in five cases of non-union where sulfonamides were used locally after bone-grafting, there were three cases of successful union but two cases of failure. Emphasis is placed upon careful preoperative preparation of the patient, and asepsis during surgery.

TABLE XIII

Relation of Age to Healing in Bone-Grafting

Ages (*Years*)	Surgery (*No of Cases*)	Results	
		Good	Poor
5 to 10	3	3	0
11 to 20	12	11	1
21 to 30	20	16	4
31 to 40	18	12	6
41 to 50	15	11	4
51 to 60	7	6	1
61 to 70	12	8	4
Totals	87	67	20

TABLE XIV

FAILURES AFTER BONE-GRAFTING

Case No.	Types of Bone Grafts: Inlay and Screws	Sliding	Onlay and Screws	Inlay and Bone Pegs	Inlay and Onlay	Dual Onlay	Inlay and Chromic Catgut	Onlay and Chromic Catgut	Drilling	Infection	Screw Only	Fracture of Graft	Sequestrectomy	Results: Good	Poor
1		1	2						1					x	
2			1								2			x	
3				1	2					2					x
4						2	1							x	
5		1								1			2		x
6		1													x
7					1							1			x
8	1					2								x	
9			1			2								x	
10								1							x
11							1								x
12								1 and 2		2					x
13			2				1			2			3		x
14					1 and 2										x
15								1							x
16			1									1			x
17						2		1						x	
18			1			2								x	
19							1								x
20					1	2									x
21						3		1 and 2		3			4		x
Totals														7	14

1 = Original operation or its complication.
2, 3, and 4 = Subsequent operations.

The follow-up of the patients in this series after operation is shown in Table XII.

The age factor in relation to successful results indicated that healing in bone-grafting operations was obtained most frequently between the ages of five and twenty years, in which consolidation failed in only one out of fifteen cases (Table XIII).

In Table XIV are summarized all the failures following bone-grafting; the type of operation, and also the number of operations to which the patient had previously been subjected, are specified. After failure of the first operation, subsequent bone-grafting gave a total of seven cases with good results (33 per cent.) and fourteen cases of persistent failure (67 per cent.).

CONCLUSIONS

1. Non-union is an avoidable complication in the treatment of fractures.

2. Greater adherence to sound principles in the treatment of fractures will lessen the tendency for pseudarthrosis.

3. In treating this complication by bone-grafting, the principles of sound fracture treatment should be employed.

4. The most efficient treatment for non-union of the shafts of the long bones is by massive autogenous onlay bone grafts or massive dual onlay grafts fixed with vitallium screws.

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BACKWARD DISPLACEMENT OF FIFTH LUMBAR VERTEBRA IN DEGENERATIVE DISC DISEASE

The Significance of the Difference in Anteroposterior Diameters of the Fifth Lumbar and First Sacral Vertebrae

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Posterior displacement of the fifth lumbar on the first sacral vertebra, interpreted as a posterior subluxation of the lumbosacral joint, received little attention until 1929, when Hibbs and Swift reported the results of operations in six cases. Williams and Yglesias stated that this condition is associated with lumbosacral facets in the frontal plane. In 1934, Johnson and Smith classified posterior displacement as an independent entity, and emphasized its importance in the causation of backache and sciatica. In 1944, Knutsson showed that it was a sign of instability of the lumbosacral junction, associated with disc degeneration. Willis, in 1935, concluded that actual backward displacement does not occur, but is only an optical illusion, due to a relative anteroposterior shortening of the body of the first sacral vertebra.

In the present study, the author will demonstrate that posterior displacement of the fifth lumbar on the first sacral vertebra is a definite pathological occurrence. It is not a separate entity, but is a mechanical consequence of degenerative disc disease. It is also proposed to show that the difference in size of the fifth lumbar and first sacral vertebrae has an etiological significance in the production of these degenerative changes.

This study is based upon 600 roentgenograms of the spine, taken on male subjects in the Medical Department of the Veterans Administration, Pittsburgh Regional Office. These patients are veterans of World War II, most of whom were discharged for backache only; a small number had other unrelated disabilities. In most cases the Service records, containing complete medical histories with roentgenographic and laboratory studies, were available.

Almost 90 per cent. of the 600 veterans were less than forty years of age, as is shown by the following figures:

Under 20 years	1 9 per cent
21 to 30 years	48 8 per cent
31 to 40 years	37 8 per cent.
41 to 50 years	11 5 per cent

The universal symptom was backache, most often in the low back; limitation of motion and sciatica were commonly associated complaints All of the roentgenograms were taken with the patients in the recumbent position.

In this group of 600 cases, there were fifty-six spines in which there was posterior displacement, of at least 4 millimeters, of the posteroinferior border of the fifth lumbar vertebra in relation to the posterosuperior border of the first sacral vertebra (Figs. 1-A and 1-B). Those cases with displacement of less than 4 millimeters were not included, because of the possibility that such a slight malalignment might be due to technical factors or to individual evaluation. These fifty-six cases represent about 10 per cent. of the group; this figure is in accord with the findings of Johnson.

Willis, in thirty-three of fifty skeletons, found a difference in the anteroposterior diameters of the fifth lumbar and first sacral vertebrae, ranging from 1.5 millimeters to 6 millimeters. He attributed this difference to the fact that the posterior surface of the

to exist usually in not more than 50 to 65 per cent. of the cases [2], the hypertonic condition of muscles has been found to be present in 100 per cent. of 1,775 acute cases of poliomyelitis of all types, recently examined.

Hypertonicity or spasm of the peripheral tissues has become recognized as one of the diagnostic manifestations in the disease. This condition, as evidenced by neck stiffness, is the earliest objective finding. Its presence in the posterior spinal muscles and in the hamstrings, long recognized, has been in the past interpreted as evidence of meningeal irritation. The same hypertonicity, differing not in the least in character, may appear in the anterior muscles of the body, as well as the posterior. It may affect any of the muscles, including those with no attachment to the spine.

While it is known that the disease becomes active in the central nervous system, yet the distinctive pain and tenderness in the peripheral tissues are very strongly suggestive of a local process in these peripheral tissues themselves.

The condition of spasm or hypertonicity does not always subside spontaneously, but may go on to cause permanent changes in the affected muscles, consisting of fibroses and contractures. In this respect, the hypertonicity of poliomyelitis is vastly different from that of other conditions. In meningitis there may be extreme hypertonicity of muscle even to the point of opisthotonus, but the muscle disorder always subsides, and the patient becomes flexible as the disease in the spinal cord regresses. From this observation, it may be reasoned that hypertonicity of nerve origin alone does not suffice as an explanation of the permanent muscle shortening which occurs in poliomyelitis. Local changes must apparently also take place in the muscle tissue. This is an extremely important possibility which should be given consideration in all future study of the disease.

The peripheral tissues of the body consist of the skin, the subcutaneous fat, the muscles, and the fascia enveloping the muscles. The symptoms in these tissues in the acute stage of the disease consist of pain, sensitivity, and contraction of the skin; atrophy of the subcutaneous fat; hypertonicity, pain, and shortening of the fascial tissue and muscle; and compression of the muscle. Each of these structures will be taken up in detail, and evidence will be given for the belief that the observed symptoms and findings suggest a local process in the tissue.

SKIN

In many cases, the skin is painful and sensitive in the acute stages of poliomyelitis, and the patient resents palpation. Even the pressure of bedclothes is sometimes uncomfortable. Pinching or stretching the skin is painful. The pain and sensitivity of the skin in the acute stage have commonly been attributed to an inflammatory process in the spinal cord, principally an affection of the sensory posterior nerve roots and the posterior columns of the spinal cord. It is to be noted, however, that the skin may remain tender and sensitive for months, long after the disease must, presumably, have subsided in the spinal cord.

Early in the disease, even in the absence of paralysis, the skin over areas of muscle spasm begins to lose its freedom of movement and to become slightly adherent to the deeper tissues. The skin thickens and, when untreated, in the chronic case is found to be fixed and inelastic. In other cases with paralysis, where there is marked muscle atrophy, there is seldom looseness or wrinkling of the skin, as would be expected from reduced bulk of underlying muscle tissue. Rather is the opposite true,—the skin contracts, becomes thick and unyielding, and loses its soft texture. It becomes agglutinated to the underlying substance and cannot be picked up easily as a separate layer of tissue.

The normal skin has creases or flexure lines crossing the skin at the joint, and the skin is fairly fixed to the deeper structures at these creases. On motion of the joint these creases deepen, and the adjacent skin usually folds over the creases to accompany the movement of the joint. It can be noted fairly early in poliomyelitis that, although the flexure lines remain, the folding of skin adjacent to these creases tends not to appear on flexion of the

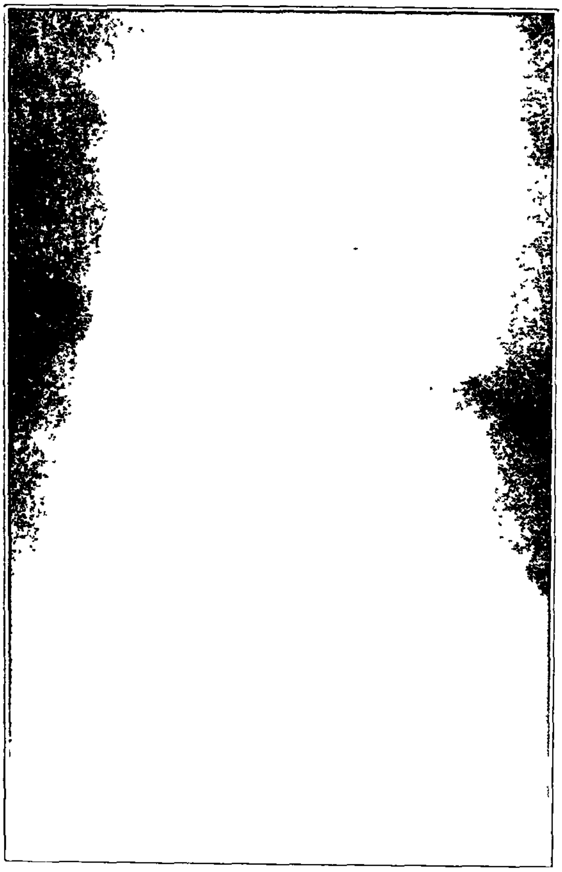

FIG. 1-A
Roentgenogram shows posterior displacement of fifth lumbar on first sacral vertebra.

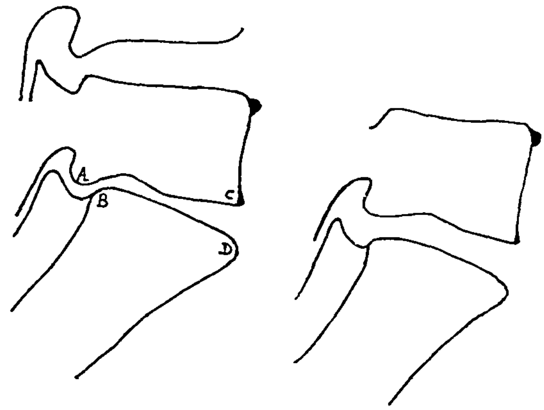

FIG. 1-B
First view is tracing of Fig. 1-A. *A-C* equals 5.1 centimeters; *B-D* equals 4.5 centimeters. Apparent displacement is 9 millimeters. Difference in anteroposterior diameters equals 6 millimeters. Actual backward displacement is 9 minus 6, or 3 millimeters. Narrowing of the disc and umbilication on the posterior aspect of the lower surface of the fifth lumbar vertebra are seen. Second tracing shows the reduction.

FIG. 2
I represents lower surface of fifth lumbar vertebra, and *II*, upper surface of first sacral vertebra. In *III*, the anterior halves of the contours are superimposed, but not the posterior halves. The continuous line represents the concave posterior border of the first sacral, and the broken line, the convex posterior border of the fifth lumbar vertebra.

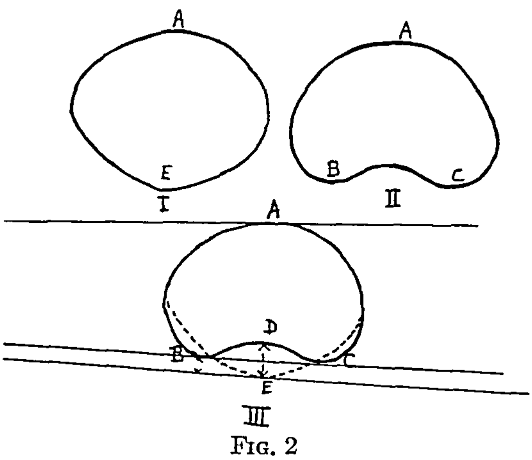

FIG. 2
A: Superimposed anterior borders of fifth lumbar and first sacral vertebrae.
B and *C:* Posterolateral borders of first sacral vertebra.
E: Posterior border of fifth lumbar vertebra.
D-E: Difference in diameters, as measured on skeleton.
B-E: Difference between projections of posterior borders, as seen on the roentgenograms.

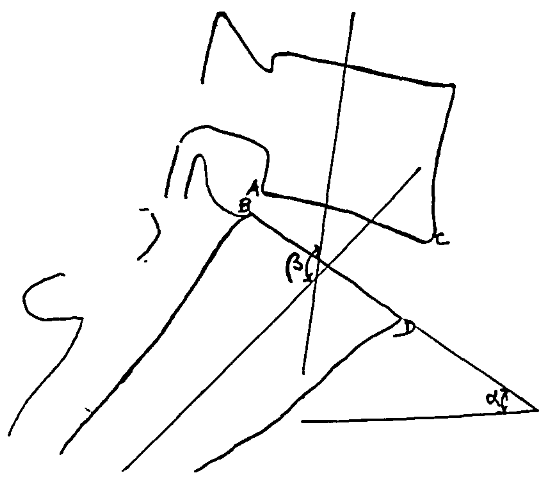

FIG. 3
A-B equals width of the posterior margin of the disc.
C-D equals width of the anterior margin of the disc.
α represents lumbosacral angle Type I.
β represents lumbosacral angle Type II.

sacral body is concave and that of the fifth lumbar body is convex (Fig. 2). He then stated that the relative shortening of the first sacral vertebra gives the illusion of an apparent displacement, and concluded that, if careful measurements of unselected skeletons demonstrate a difference in anteroposterior diameters six times as often as roentgenograms do on patients having back symptoms, this finding can have no clinical significance.

joint. This would seem to be the result of an affection of the skin itself, and is presumably due to thickening and loss of elasticity of the skin. This affection of the skin can be observed in areas where there is no muscle paralysis, hence where the associated motor cells of the spinal cord are uninvolved. For this reason, the condition can logically be considered a local disturbance rather than a neurotrophic manifestation.

SUBCUTANEOUS FAT

The subcutaneous fat atrophies quickly in the acute stage of the disease, and some patients appear thinned and almost emaciated within a period of two to three weeks. This is not always a generalized disturbance, but is most apt to appear in areas where there has been definite spasm and hypertonicity. The condition may be especially noticed in the region of the chest, where the skin is observed to become adherent to the underlying bony structure, so that the ribs become very apparent. The chest itself becomes flattened, and the anterior wall of this structure becomes depressed. The condition is not dependent upon paralysis and atrophy of the thoracic muscles, but occurs in many cases in which there is no evidence of paralysis of these muscles. Posteriorly the spinous processes become very prominent as the subcutaneous fat disappears and the skin contracts. The skin here becomes thick and unyielding as the disease progresses.

MUSCLE

The muscle and its enclosing fascia present the most striking evidence of a local process. The hypertonic condition called spasm has been found present in each of these cases of poliomyelitis in the acute stage, and this may affect any of the muscles. The disorder varies in intensity; in some cases there is merely a hypertonicity, but in many cases there is an associated spontaneous pain which may be extremely severe and signalizes an abnormal condition within the muscle. The affected muscle is often exquisitely tender to pressure. The muscle becomes short; attempts to stretch it may be very painful to the patient. This shortening of muscle has often been stated to be a physiological response to weakness of the opposing muscle,—that is, weakness of one muscle upsets the normal balance, so that the supposedly unaffected opponent contracts and shortens. This theory of strong normal muscles pulling against weak ones in the past was further interpreted to explain the contractures and deformities associated with poliomyelitis. It will be noticed, however, that the shortening muscle, which was supposedly normal, is actually tender and painful. A normal muscle should not be painful. Many of these shortened muscles have no voluntary contractile power whatever. Also, it will be observed that the shortening muscle tends to become flattened and narrowed, as if it were becoming compressed, rather than being rounded and bulging, as would occur if this muscle were normally contracting.

The theory of muscle imbalance as a cause of deformity implies that the muscle causing the deformity has retained its motor-nerve supply. This belief does not coincide with the facts, as severe deformity may occur in a limb where there is absolutely no evidence of motor innervation of any of the muscles. Permanent deformities persist when no muscle power returns, and where it must be presumed that the correlated anterior-horn cells of the spinal cord have been destroyed by the disease. A cause other than muscle imbalance must be contrived in order to explain deformity in this circumstance.

It has been observed that the muscle in spasm may remain short after the death of the patient, even in those who die within a few days of the onset of the disease. Mere neurogenic hypertonicity should not cause permanent change in muscle, especially if it is only of brief duration. Thus, even though laboratory proof of the activity of the virus itself in the muscle tissue has not been large in volume, the evidence is highly suggestive from clinical observation that there occurs at some stage of the disease a local process, involving the muscle tissue.

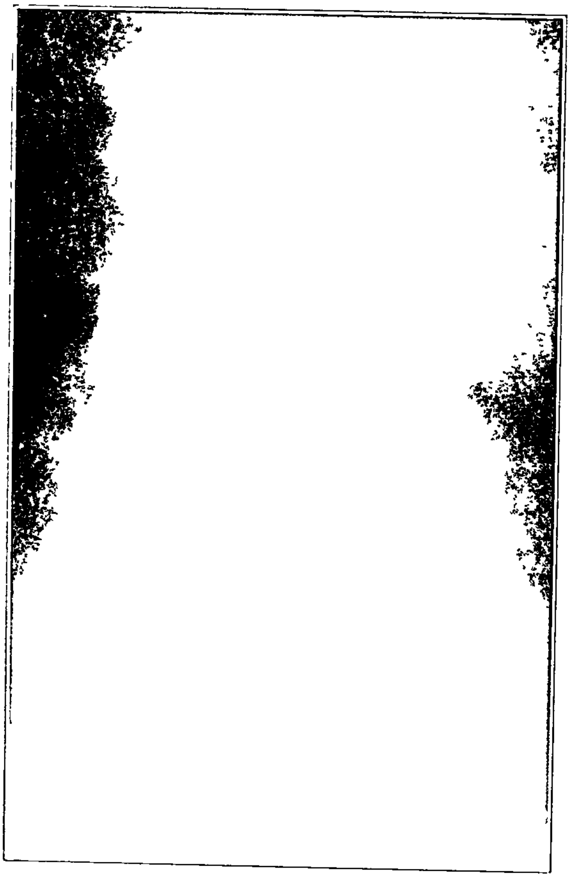

Fig. 1-A

Roentgenogram shows posterior displacement of fifth lumbar on first sacral vertebra.

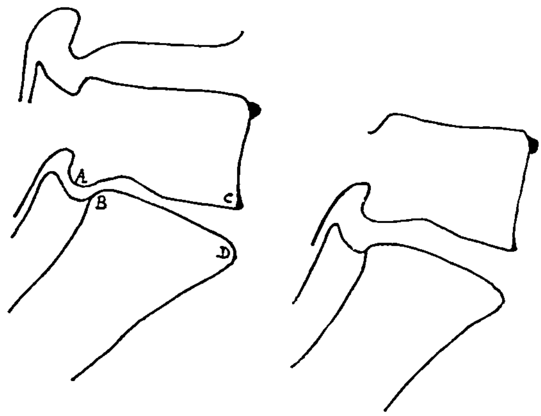

Fig. 1-B

First view is tracing of Fig. 1-A. *A-C* equals 5.1 centimeters; *B-D* equals 4.5 centimeters. Apparent displacement is 9 millimeters. Difference in anteroposterior diameters equals 6 millimeters. Actual backward displacement is 9 minus 6, or 3 millimeters. Narrowing of the disc and umbilication on the posterior aspect of the lower surface of the fifth lumbar vertebra are seen. Second tracing shows the reduction.

Fig. 2

I represents lower surface of fifth lumbar vertebra, and *II*, upper surface of first sacral vertebra. In *III*, the anterior halves of the contours are superimposed, but not the posterior halves. The continuous line represents the concave posterior border of the first sacral, and the broken line, the convex posterior border of the fifth lumbar vertebra.

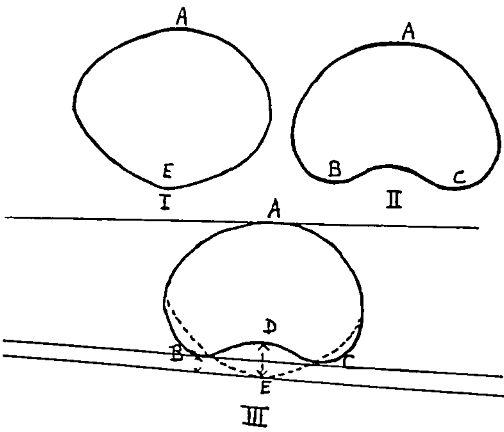

Fig. 2

A: Superimposed anterior borders of fifth lumbar and first sacral vertebrae.

B and *C:* Posterolateral borders of first sacral vertebra.

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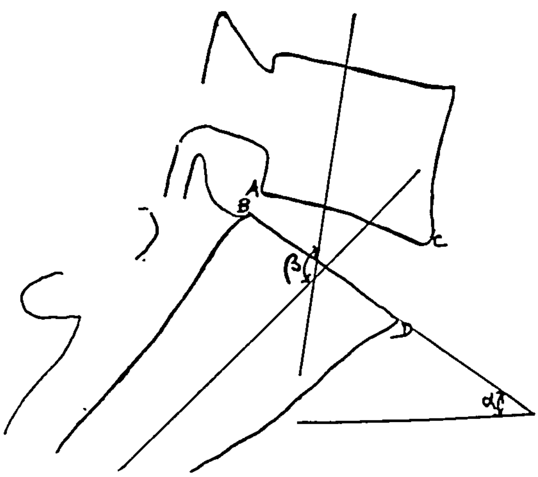

Fig. 3

A-B equals width of the posterior margin of the disc.

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α represents lumbosacral angle Type I.

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sacral body is concave and that of the fifth lumbar body is convex (Fig. 2). He then stated that the relative shortening of the first sacral vertebra gives the illusion of an apparent displacement, and concluded that, if careful measurements of unselected skeletons demonstrate a difference in anteroposterior diameters six times as often as roentgenograms do on patients having back symptoms, this finding can have no clinical significance.

FASCIA

There is reason to suspect that the primary disorder in the shortened muscle in the acute stage of the disease involves the fascial covering of the muscle, as well as the muscle tissue itself. The muscle is enclosed in a tight-fitting sleeve of fascia, which confines the muscle and preserves the normal shape of the muscle. This fascial covering is tough, fibrous, and inelastic, and keeps the enclosed muscle under constant slight tension. It has already been mentioned that a muscle affected by spasm tends to become narrowed and flattened in addition to its shortening. Such a muscle is tender and painful. Any circumstance which would increase the pressure within the fascial envelope, such as swelling of the muscle or shrinking of the fascia, might seriously damage the muscle tissue. Increased tension upon the muscle, for instance by contraction of the enclosing fascial envelope, would interfere with circulation and would deprive the muscle of oxygen. The anoxia or ischaemia would explain the pain in the muscle in the acute stage and the replacement of muscle substance by fibroid tissue later in the disease. Muscles which have been in spasm have the appearance of having been compressed.

More objective evidence of the possibility of direct involvement of fascia by the disease is that certain of these tissues with little or no muscle connection are frequently affected and tend to become short. This has been observed in the case of the iliotibial band of the thigh, contracture of which often causes flexion-abduction deformity of the hip. The plantar fascia of the foot also frequently becomes short, resulting in a highly arched or cavus foot. Such fascial tissues have no known connection with the anterior-horn cells of the spinal cord, and yet they are affected in the disease of poliomyelitis.

EFFECT OF TREATMENT

Evidence of circumstantial nature that the disease attacks the more external tissues of the body is obtained by observation of the effect of treatment applied to the peripheral tissues, on the assumption that the local parts actually are affected. If all of the aftereffects of poliomyelitis could really be explained on the basis of the disease process in the nervous system, then treatment applied to the body periphery would have little or no effect upon the eventual outcome of the patient. It is extremely unlikely that such treatment would, to any appreciable degree, interrupt or modify organic disease in the spinal cord, so as to alter materially the effect of a central-nerve lesion upon the peripheral tissues. However, moist heat and other procedures applied to the body surface do relieve pain and do relax the hypertonic structures, with the result that contractures and deformities do not materialize. The blueness, coldness, skin thickening, and excessive perspiration thought due to circulatory changes are prevented, and the common neurotrophic disturbances, such as chilblains and ulcers, are also eliminated by such treatment. The circulatory and trophic changes so frequently observed in the past cannot reasonably be assumed to be due to the action of the disease in the central nervous system, when these deleterious effects can be prevented by treatment of the peripheral tissues.

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Roentgenograms do not show the projection of the true anteroposterior diameter of the first sacral vertebra but, instead, that of the distance between the anterior and posterolateral borders (Fig. 2). This distance is greater than the anteroposterior diameter in concave vertebral bodies. Obviously, Willis found a higher incidence of lesser anteroposterior diameters of the first sacral vertebra than one would by measuring, on the roentgenograms, the distance between the anterior and posterolateral borders. In this paper the term "anteroposterior diameter" will be used to denote the distance between the anterior and posterolateral borders on the roentgenograms, but one should remember that this is not the true diameter.

The amount of displacement and the differences in diameters (Fig. 1-B) were computed in the fifty-six cases; the averages were 6.7 millimeters and 3.5 millimeters, respectively (Table I). In eight instances, the difference was about equal to the apparent displacement. On the other hand, in seven instances, there was no difference in diameter (Fig. 6), and in the forty-nine remaining cases (87 per cent.), the difference was at least 2 millimeters.

From the total group with backache, of 200 unselected cases without backward displacement and with no other lumbosacral abnormality except occasional spina bifida, the diameter of the fifth lumbar vertebra was on the average only 0.5 millimeter more than that of the first sacral vertebra, with a maximum of 3 millimeters. In about 50 per cent. of the cases, the diameters were equal; and in 10 per cent., that of the first sacral vertebra was slightly greater than that of the fifth lumbar vertebra. A difference in diameters between the fifth lumbar and first sacral vertebrae was found in 87 per cent. of the cases with backward displacement, and no appreciable difference was found in the control group.

In the total series of 600 roentgenograms, thirty-nine cases of advanced degenerative disc disease were found, twenty of which were located at the lumbosacral disc; the others were found at various levels of the spine. This diagnosis was made in the presence of a narrow disc, associated with various degrees of sclerosis, hypertrophic changes, umbilications on the lower surface of the fifth lumbar vertebra, and subdislocation of the facets. The twenty cases of this condition were carefully differentiated from those in which the uniformly narrow disc was seen between a transitional vertebra and the sacrum.

Seventeen of the twenty cases of degenerative lumbosacral disc disease were in the group with backward displacement, and three occurred among the remaining 544 cases. This means that 85 per cent. were associated with backward displacement, and that 30 per cent. of the patients with backward displacement had disc disease. The incidence of lumbosacral disc disease in the group without backward displacement was only 0.5 per cent.

TABLE I

COMPARISON OF FINDINGS IN GROUP WITH BACKWARD DISPLACEMENT AND IN CONTROL GROUP

	Group with Backward Displacement (56 Cases)		Control Group (200 Cases)	
	Mean	Range	Mean	Range
Amount of displacement	6.7 mm.	4 to 10.5 mm.	0	0
Difference in diameters	3.5 mm.	0 to 8 mm.	0.5 mm.	1 to 3 mm.
Posterior disc width	3.5 mm.*	0 to 7 mm.*	6 mm.	0 to 11 mm.
Anterior disc width	17.7 mm.*	13 to 23 mm.*	17.3 mm.	10 to 28 mm.
Lumbosacral angle Type II	136°	115° to 149°	137.8°	110° to 155°
Lumbosacral angle Type I	39°	23° to 60°	44°	19° to 70°

* The 17 cases of advanced degenerative disc disease are not included.

FASCIAL REPAIR FOR POLIOMYELITIC PARALYSIS OF THE ABDOMINAL WALL IN ADULTS

BY MAJOR GEORGE T. WALLACE AND CAPTAIN WILLIAM J. WEST

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Until Lowman brought the subject to our attention in 1932, the importance of abdominal-wall defects as related to infantile paralysis was not recognized. Lowman, in attempting to account for the cause, development, and prevention of scoliosis in this disease, originally reported twelve cases. During the intervening years, many other workers have contributed to this subject. Dickson reported forty-four cases of abdominal fascial repair, and went further in utilizing fascial implants in an attempt to correct cervical scoliosis. He advised attachment of fascial straps from the spine of the scapula to the spines of the thoracic vertebrae or to the origin of the trapezius on the affected side. He also suggested such surgical repair for the loss of the serratus anterior.

Mayer divided patients suffering trunk involvement into three groups. In the first group, were those with development of lumbothoracic scoliosis and a so-called pelvic obliquity, involving unilateral contracture of the quadratus lumborum and the internal and external oblique muscles on the same side, with paralysis of these muscles on the opposite side. If the quadratus lumborum is not paralyzed, a lumbothoracic scoliosis develops without pelvic obliquity, thus constituting a second group of patients. A third group, according to Mayer, were those with bilateral paralysis of the recti abdominis with bilateral weakness of the internal and external oblique muscles, resulting in severe lumbar lordosis and sagging of the abdominal wall. Mayer has followed his cases for a number of years, and it is his conviction that, in severely involved cases, fascial grafting should be performed in conjunction with spine fusion, in order to prevent recurrent scoliosis. He has utilized flat fascial grafts, rather than straps of fascia as suggested by Lowman. It can be stated unequivocally that the integrity of the oblique muscles, as well as of the rectus and quadratus lumborum, is of paramount importance in the development of deformities of the spine, the thoracic cage, and the pelvic bones.

Despite the pioneer work in the use of fascial grafts, the surgical procedure still has not been accepted by all clinics dealing with severely paralyzed patients. Perhaps this hesitance on the part of the orthopaedic surgeon to accept abdominal fascial grafting as a routine part of the armamentarium of surgical procedures in the reconstructive phase of the treatment of poliomyelitis is due to his own inability to recognize the advisability of the procedure. Then, too, some patients are inclined to accept their deformities, and are unwilling to attempt to have them corrected. However, most patients will readily accept any procedure that may offer improvement.

At the Army Poliomyelitis Center, abdominal fascial transplantation is approached from a different point of view than that of the civilian surgeon. It is well known that only occasionally in the adult does abdominal-muscle imbalance cause sufficient spinal curvature to warrant concern. Since all of the patients seen during the War were Army personnel, it necessarily follows that they were all adults before the onset of the disease. Only a small number of patients have had a pelvic obliquity severe enough to warrant a surgical procedure from that standpoint. It is well to bear in mind that the patients sent to this Center manifested severe paralysis which was often generalized. In the majority of our cases, the entire muscular system had been affected to some degree. Those patients with only one or two isolated muscles involved have not been prominent in the total number of cases treated, and have been treated in other Army general hospitals. A recent

TABLE II

CORRELATION OF DEFINITIONS OF LUMBOSACRAL ANGLES TYPE I AND TYPE II IN THE CONTROL GROUP

Lumbosacral Angles	No. of Cases	Per Cent.
Both normal	56	28
Both abnormal (to some degree)	8	4
Both abnormal (marked discrepancy in degree)	26	13
One normal, the other abnormal	110	55
Totals	200	100

This close correlation between degenerative disc disease and backward displacement is further emphasized by the fact that, in the remaining thirty-nine cases of backward displacement without advanced disc disease, the width of the posterior aspect of the disc was found to be markedly narrowed. The average anterior and posterior widths were 17.7 millimeters and 3.5 millimeters, respectively (Fig. 3). In eleven instances (28 per cent.), the lower surface of the fifth lumbar vertebra actually rested upon the posterior edge of the first sacral vertebra (Figs. 4-A and 4-B). In ten instances, deep umbilications were present on the posterior half of the lower surface of the fifth lumbar vertebra, indicating breaks in the fibrocartilaginous plate.

In the control group, the average anterior and posterior widths were 17.3 and 6 millimeters, respectively. In only two instances (1 per cent.), were the posterior borders in contact.

A comparison of these figures (Table I) shows that the anterior aspect of the disc is not affected, but that the posterior aspect is markedly narrowed. This narrowing has been considered by many authors as indicative of degenerative changes in the posterior fibers of the annulus fibrosus. The writer thought that the lumbosacral angles should be compared in the study group and in the control group to find out whether or not there was a correlation between a narrowed posterior aspect of the lumbosacral disc and an exaggerated lumbosacral angle.

To investigate this point, two definitions of the lumbosacral angle were used because as far as the author knows, it has not been determined which more accurately depicts the mechanics of the lumbosacral joint (Fig. 3). In the first definition (lumbosacral angle Type I), the angle between the upper surface of the sacrum and the horizontal is measured the upper limit of normal being given as 42 degrees [4, 12]. In the second definition (lumbosacral angle Type II), the angle between the axis of the sacrum and the axis of the fifth lumbar vertebra is measured, the lower limit of normal being given as 130 degrees[1]. According to these limits, 55 per cent. of the control group had abnormal Type I angles

TABLE III

TYPES OF LUMBOSACRAL FACETS IN THE CONTROL GROUP

Type of Facet	No. of Cases	Per Cent.
Frontal	137	68.5
Oblique cylindrical	20	10.0
Asymmetrical	36	18.0
Sagittal	7	3.5
Totals	200	100.0

analysis of ninety-six poliomyelitis patients in this Hospital, on the basis of abdominal involvement, indicates that twenty-five (26 per cent.) were normal; seventeen (18 per cent.) had mild paralysis; thirty (31 per cent.) had moderate paralysis; and twenty-four (25 per cent.) had severe paralysis. Thus, 74 per cent. had some degree of abdominal paralysis. Although our patients have shown this high percentage of abdominal involvement, not more than 2 or 3 per cent. have had a fixed spinal curve, demonstrable by roentgenograms. Although we have not been primarily concerned with the development of scoliosis, in those patients with severe abdominal involvement, the problem of rehabilitation has been of extreme concern to us. The attempt to render ambulatory a patient who has complete involvement of both legs and abdomen, with or without arm involvement, and to enable him to perform the more simple activities of life, engages the greatest ingenuity on the part of all responsible for his progress.

The Surgeon General has specified that the patients concentrated in the Poliomyelitis Center must reach maximum hospital benefit before being discharged. It has been our aim to try to make these patients as self-dependent as possible. It has long been known that in paralyzed muscles, the greatest degree of improvement in strength occurs within the first six to nine months. Improvement noted thereafter may be due partly to further return of strength in the involved muscles or, more commonly, to the fact that the patient learns to make the best use of his uninvolved muscles and the muscles that have returned to a functional state.

The purpose of this paper is (1) to report twelve abdominal fascial transplantations in nine cases of residual abdominal paralysis, and (2) to show concretely the degree of improvement. We are cognizant of the fact that our group of cases is small compared to the groups formerly reported. We also realize that, in some of our patients who have been discharged more recently, insufficient time has elapsed for full evaluation of the results. Nevertheless, sufficient time has elapsed in most of our cases to give a true picture of improvement. Some of the patients will soon be separated from the Service, and will not be available for further observation. However, it is only logical that, if the patient is showing gradual improvement under our observation, he should continue to improve with no reversals until maximum benefit has been obtained.

Candidates for Surgery

The patients upon whom abdominoplasty has been performed may be divided into two groups on the basis of function. Three patients (Cases 5, 6, and 7) had no strength in the abdominal wall or quadratus lumborum. These might be considered to be in Group III, according to Mayer's classification. All three had severe forward tilting of the pelvis and sagging of the abdominal wall. Cases 1, 2, and 3 might also be considered to be in this same group. The latter group of patients did have some residual strength in the upper portion of the recti and oblique muscles unilaterally, but this strength was of little benefit to them, inasmuch as the lower abdominal wall was completely paralyzed, and there was no transmission of power from the relatively intact upper abdominal wall to the pelvis. Cases 4, 8, and 9 fall into a second group functionally, because in these patients the muscles which elevate the hip were strong enough before operation to allow them to clear the lower extremities with the use of crutches. However, due to loss of stability anteriorly, their balance was extremely poor, and most activities requiring balance were difficult to perform. Neither was there opposition for the serrati to pull against, thus enabling the full use of the good upper extremities.

The complete inability to clear the foot with crutches, as seen in Cases 5, 6, and 7, and also in Cases 1, 2, and 3 to a lesser degree, has been the main indication for abdominal repair. The rehabilitation of these patients has been considerably more difficult than in the second group (Cases 4, 8, and 9). However, even this latter group have shown marked improvement from this procedure, as will be shown on the Improvement Record Chart.

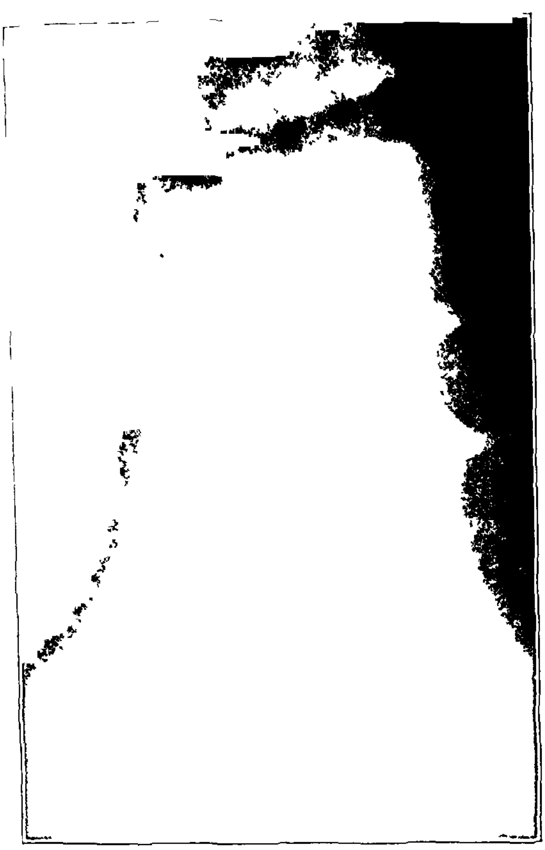

FIG. 4-A

FIG. 5-A

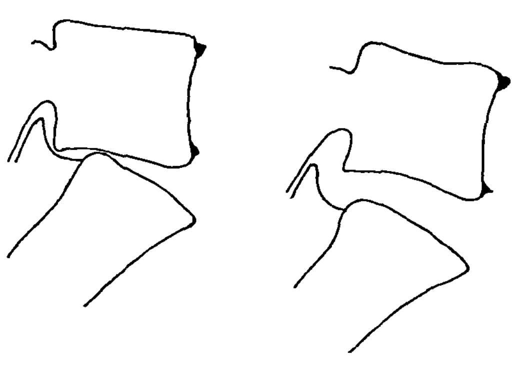

FIG. 4-B

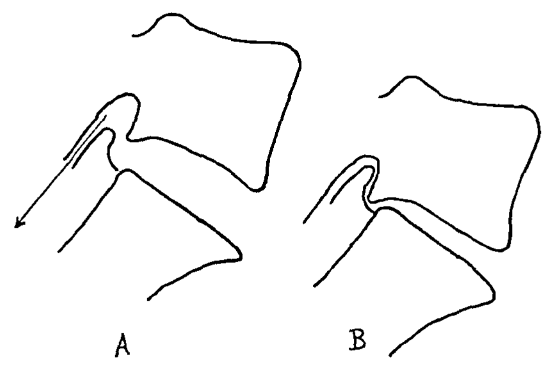

FIG. 5-B

Fig. 4-A: Roentgenogram showing backward displacement.

Fig. 4-B: Anteroposterior diameter of fifth lumbar vertebra equals 4 centimeters, anteroposterior diameter of first sacral vertebra equals 3.5 centimeters. Apparent displacement is 10 millimeters. Difference in anteroposterior diameters is 5 millimeters. Actual backward displacement equals 10 minus 5, or 5 millimeters. The lower surface of the fifth lumbar vertebra is resting on the posterior edge of the first sacral vertebra, with subdislocation of the facets. Second tracing shows the reduction.

Fig. 5-A: Roentgenogram showing backward displacement.

Fig. 5-B: Anteroposterior diameter of fifth lumbar vertebra equals 4.1 centimeters. Anteroposterior diameter of first sacral vertebra equals 4.1 centimeters. Apparent displacement is the same as actual backward displacement, or 4 millimeters. The sacral facets are in contact with the posterior surface of the fifth lumbar vertebra and almost in contact with its pedicles. The tracings show the mechanism of backward displacement. *B* is the tracing of the roentgenogram. *A* is the tracing obtained in giving to the disc its normal width. The arrow shows the direction of the settling of the fifth lumbar vertebra when the disc becomes narrowed, as a result of the interlocking of the facets.

and 8 per cent. had abnormal Type II angles. For a group with backache, the former figure appears too high and the latter figure too low. Table II indicates the lack of correlation. Either the definitions or the values given as normal limits are not adequate.

A comparison of the lumbosacral angles (Type I and Type II) found in both the group with backward displacement and in the control group shows that they are approxi-

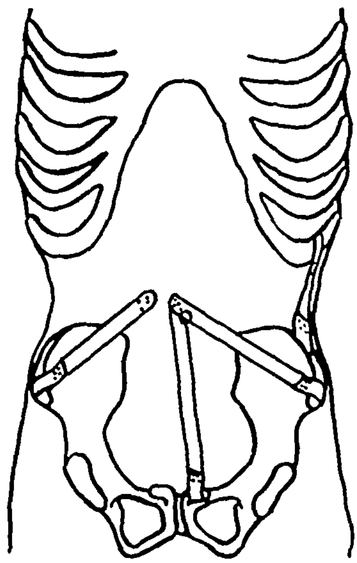

FIG. 1-A

CASE 1. Muscle status and fascial repair.

Right		Left
3	Quadratus lumborum	0
4	Serratus anterior	4
3	Erector spinae	3
3	Upper rectus abdominis	4
0	Lower rectus abdominis	0

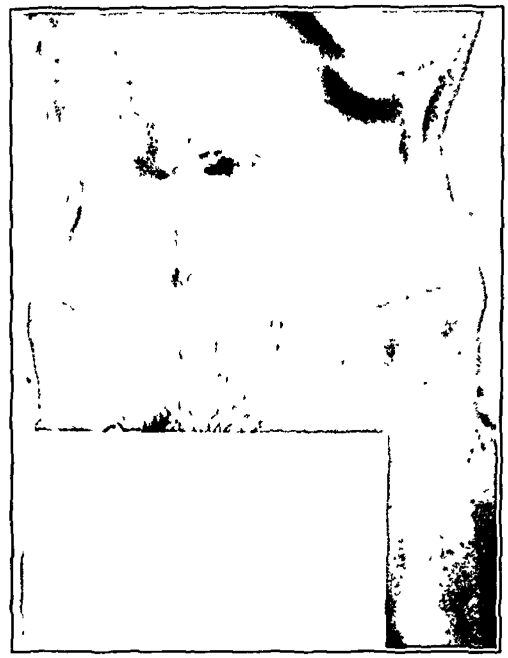

FIG. 1-B

Right		Left
3	Upper obliquus abdominis	3
0	Lower obliquus abdominis	0
5	Upper extremities	5
0	Lower extremities	0

Fig. 1-B: Photograph taken five months after operation, showing how fascial bands assume appearance of strong cords.

The legends for the illustrations explain the individual muscle involvement for each patient we have selected for abdominal fascial transplantation. The figures illustrate anatomically the location of the fascial straps at the time of surgery.

The degree of muscle involvement has been determined by the tests, evolved by Lowman, to demonstrate the degree of paralysis. As Mayer has pointed out, it is markedly difficult to gauge accurately the strength of the muscles in question, because of the inadequacy of knowledge of the kinesiology of these muscles. We have not included in detail the arm and leg involvement, but have only considered the extremities as units.

We have employed the following grading:

0 signifies no contraction felt in the muscle;

1 signifies a trace (the contraction is felt in the muscle, but there is no significant movement of the part);

2 signifies a poor muscle, which moves the part through a partial range when gravity has been eliminated;

3 signifies a fair muscle and one in which the muscle can move the part through a complete arc, the muscle tiring after from three to six contractions;

4 signifies a good muscle, in that it completes the arc against gravity with a medium amount of resistance several times without showing fatigue, but this muscle tires quickly or is unable to complete the arc against maximum resistance;

5 signifies a normal muscle, in that the muscle completes an arc against gravity, and will accept maximum resistance several times without showing signs of fatigue.

SURGICAL TECHNIQUE

Preoperative Care

Patients with abdominal paralysis not infrequently are unable to indulge in sufficient physical activities to maintain their weight at a minimum degree for their stature. In

TABLE IV

Types of Lumbosacral Facets in the Group with Backward Displacement

Type of Facet	No. of Cases	Per Cent.
Frontal	39	69.6
Oblique cylindrical	5	8.9
Asymmetrical	11	19.7
Sagittal	1	1.8
Totals	56	100.0

mately the same. This clearly demonstrates that the narrowing of the posterior aspect of the disc is not due to an exaggerated lumbosacral angle, and that the explanation for the damage to the posterior fibers of the annulus fibrosus must be found elsewhere.

It has often been stated that lumbosacral facets in the sagittal plane give a more stable joint than those in the frontal plane, and that the most unfavorable situation exists when the facets are asymmetrical,—frontal on one side and sagittal on the other. Actually, the facets are often cylindrical, but in most instances they are predominantly either in the frontal or the sagittal plane. Hibbs and Swift correlated backward displacement with frontal facets, ascribing more laxity to this type of joint; and later Williams described how this is an essential feature in the mechanism of backward displacement. To investigate the correlation between the facet types and backward displacement, their distribution in the control group and in the study group was noted.

In the control group (Table III), facets in the frontal plane are by far the most common and, therefore, must be considered the normal anatomical variety. This seems logical if one considers that the essential role of the lumbosacral facets is to prevent, by their interlocking, anterior slipping.

The distribution of facets in the backward displacement group is shown in Table IV. In the only instance of sagittal facets alone, the apparent displacement was entirely accounted for by the difference in the diameters of the fifth lumbar and first sacral vertebrae. Also, those facets in the cylindrical oblique and asymmetrical categories were predominantly in the frontal plane. It must be remembered that frontal facets of the lumbosacral joint are not strictly in the frontal plane, but are inclined posteriorly (see arrow in Fig. 5-B).

DISCUSSION

From the data presented, the following facts can be stated concerning backward displacement of the fifth lumbar vertebra on the first sacral vertebra:

1. From roentgenograms, the author has confirmed the observations made by Willis from measurements of skeletons,—namely, that there is often a difference in the diameters of the fifth lumbar and first sacral vertebrae. This difference existed in 87 per cent. of the cases with backward displacement, and in practically none of the control group.

2. This difference in diameters was found to account for only about one-half of the apparent backward displacement in 85 per cent. of the cases in this series, thus disproving the suggestion that such displacement is only an optical illusion.

3. Backward displacement is usually associated with degenerative changes in the posterior fibers of the annulus fibrosus and a high incidence of advanced degenerative disc disease.

4. From the facts stated as No. 1 and No. 3 above, we see that there is a correlation between differences in diameters and disc disease.

5. There is no exaggeration of the lumbosacral angle in backward displacement.

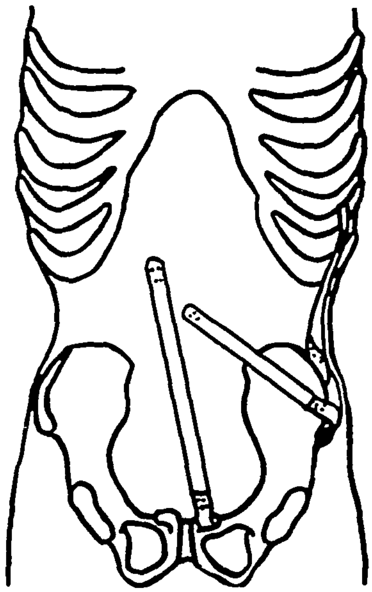

FIG. 2

CASE 2. Muscle status and fascial repair.

Right		Left
3	Quadratus lumborum	0
4	Serratus anterior	4
2	Erector spinae	2
0	Upper rectus abdominis	0
0	Lower rectus abdominis	0
3	Upper obliquus abdominis	0
0	Lower obliquus abdominis	0
3	Upper extremities	4
0	Lower extremities	0

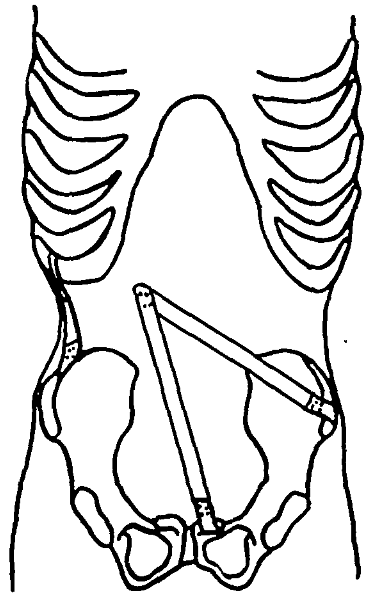

FIG. 3

CASE 3. Muscle status and fascial repair.

Right		Left
0	Quadratus lumborum	3
3	Serratus anterior	4
4	Erector spinae	4
4	Upper rectus abdominis	0
0	Lower rectus abdominis	0
3	Upper obliquus abdominis	0
2	Lower obliquus abdominis	0
4	Upper extremities	4
0	Lower extremities	0

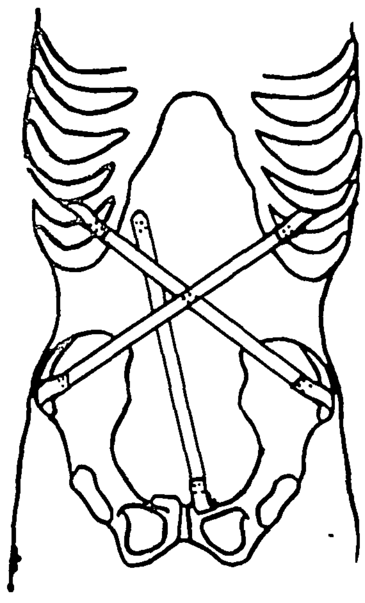

FIG. 4-A

CASE 4. Muscle status and fascial repair.

FIG. 4-B

Right		Left
4	Quadratus lumborum	4
4	Serratus anterior	4
2	Erector spinae	2
3	Upper rectus abdominis	0
0	Lower rectus abdominis	0
0	Upper obliquus abdominis	0
0	Lower obliquus abdominis	0
4	Upper extremities	4
0	Lower extremities	3

Fig. 4-B: Photograph taken five months after operation, showing how tightly fascial straps should be inserted in order to accomplish maximum function.

6. The lower lumbar and the upper sacral facets are of frontal or predominantly frontal type, and are in a plane directed downward and backward.

The cause of backward displacement lies in the narrowing of the disc. The slipping of the inferior facets of the fifth lumbar vertebra, due to a narrowing of the disc, cannot but take place in a downward and backward direction, carrying the entire body of the fifth lumbar vertebra backward in its relationship to the first sacral segment (Fig. 5-A). Degenerative disc disease or degenerative changes in the posterior aspect of the annulus fibrosus come first, and posterior displacement is a mechanical consequence. The displacement is greater, as demonstrated by Knutsson, when the roentgenograms are taken with the spine in hyperextension; this is due to the fact that hyperextension exaggerates the overriding of the facets and brings out the joint instability.

The amount of displacement will depend upon the obliquity of the facets. This displacement will not be appreciable if the facets are almost vertical (as in the thoracic or lumbar regions), and will reach a maximum for a certain optimum obliquity. The actual backward displacement is the excess of the apparent displacement over the difference between the lengths of the apposing borders of the fifth lumbar and first sacral vertebrae.

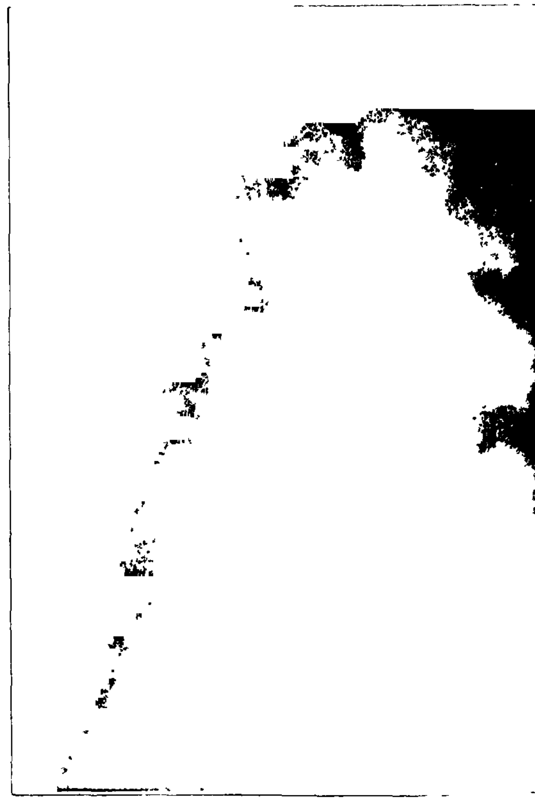

FIG. 6

Anteroposterior diameter of fifth lumbar vertebra equals 4.7 centimeters; anteroposterior diameter of first sacral vertebra equals 4.3 centimeters. Apparent displacement is 7 millimeters. Difference in anteroposterior diameters is 4 millimeters. Actual displacement equals 7 minus 4, or 3 millimeters. Deep umbilication is present on the posterior aspect of the fifth lumbar vertebra, and the postero-inferior border of the fifth lumbar vertebra is in contact with the pedicles of the first sacral vertebra.

It has been shown that both a high incidence of degenerative changes in the lumbosacral disc and a shortened first sacral vertebra are found in the group with backward displacement. It has also been seen that, outside of this group, there was no difference in size of the fifth lumbar and first sacral vertebrae, and a very low incidence of disc disease. The incidence of degenerative changes in the annulus fibrosus is no higher in the control group with backache than it was in the series of symptomless males reported by Brav, Bruck, and Fruchter. In both series, the posterior width of the discs was 6 millimeters. This leads to the inference that there is a correlation between a shortened first sacral vertebra and degenerative changes in the lumbosacral disc.

When such a difference in size exists, the posterior border of the fifth lumbar vertebra overhangs that of the first sacral vertebra, so that the posterior fibers of the annulus fibrosus are oblique instead of vertical. This creates an abnormal strain on these fibers, and accelerates the processes of hyalinization and fissuring which take place during life[2,3,4]. This fissuring opens avenues to leakage and dehydration of the nucleus pulposus. The narrowing of the posterior margin results from the degenerative changes in the annulus fibrosus and is followed, as the nucleus pulposus shrinks, by thinning of the whole disc. Therefore, one sees that a shortened first sacral vertebra increases the fragility of the lumbosacral disc in the young adult male.

The comparison of the symptoms in the cases with backward displacement and in the remaining group was striking. Those men with backward displacement of the fifth lumbar vertebra had a much higher incidence of severe low backache, sciatica, and herniated disc

several of our cases, a reduction diet was necessary for as long as two or three months, in order to reduce the patient's weight sufficiently, so that he would be a suitable candidate for this major surgical procedure. Excessive adipose tissue in the abdominal wall only adds mechanical difficulty during the operation.

Prior to operation, each of these patients had a thorough examination from an anaesthetic point of view. Frequently, with abdominal paralysis, the diaphragm is also paralyzed. Such a condition offers a considerable hazard, and the surgeon should appreciate the condition, if it is present, before surgery is contemplated. If any chest complications develop postoperatively, roentgenograms may reveal an elevation of the diaphragm. If there are no preoperative roentgenograms, the surgeon is unable to determine whether the patient had a paralyzed diaphragm preoperatively, or whether the elevation is a secondary complication from the surgery. For this reason, every patient should have a preoperative roentgenogram of the chest.

Nitrous oxide is adequate in the majority of cases, since only first-plane anaesthesia is necessary, and the operation usually lasts two hours or longer. Some patients have needed intratracheal intubation, because of the position required on the table after the fascial transplants have been sutured into place. In these cases it was necessary to employ either pentothal sodium or ether in conjunction with the nitrous oxide to allow sufficient relaxation for the intubation procedure. If there is any paralysis of the muscles of respiration, intubation should be employed. One of our patients (Case 7) had previously had a serious shrapnel wound of the left lung. In this instance, for both operative stages, spinal anaesthesia was used satisfactorily in conjunction with nitrous oxide and pentothal sodium.

Operative Technique

The location of the fascial straps is determined by considering the paralysis in each individual case. In those cases wherein no significant muscle power could be demonstrated in the abdominal wall, anteriorly or laterally, it has been our plan to perform two operative procedures (Cases 4, 5, 6, and 7). The first stage is accomplished by making cross straps from the ninth rib just inside the nipple line to the opposite ilium immediately behind the anterior superior spine on both sides. When the major cross straps have been implanted, we have endeavored to connect them with the anterior rectus sheath cephalad to the umbilicus (Figs. 6 and 8). This is done because the connection above the umbilicus serves as a link, releasing the strain on the transposed fascia. Secondly, should the patient later have a muscle rating of "poor" or "trace" cephalad to the umbilicus, the fascia may then give some resistance to this weakened muscle, if it has been directly connected to it and is not simply overlying it. At the time of the second operative stage, the rib cage and the pelvis are connected laterally from the tenth rib in the mid-axillary line to the crest of the ilium by fascial straps. The latter attachment is either in the mid-axillary line or more posterior, depending upon the strength of the quadratus lumborum. At this time, an additional strap of fascia is utilized to give the paralyzed abdominal wall support in the midline anteriorly from the chondro-osseous junction of the ribs to the opposite superior pubic ramus. This is intended to supplant the work of the rectus abdominis, and to diminish marked lumbar lordosis. It is technically impossible to perform such extensive surgery in one operative stage, as the patient would have to be on the operating table for too long a period of time. We feel that the making of the cross straps in the completely paralyzed abdominal wall should be done first. They are more important structurally than the lateral straps or the anterior strap, and are primarily intended to supplant the trunk-twisting muscles (the obliques, primarily). Also, they give the serratus anterior something to pull against, thus making the upper extremity much more useful to the patient. One operative procedure is sufficient, if only the two long cross straps are to be inserted (Figs. 8 and 9). Similarly, only one operation is necessary if three or four short straps of fascia are needed (Figs. 1-A, 2, and 3).

syndromes. Most of the diagnostic and surgical procedures for herniated discs were performed on these fifty-six patients. From the records, it was found that the results of these procedures were not satisfactory; and, at the time of the roentgenographic examination, the symptoms were not improved.

These symptoms are attributed to pressure on the nerve roots in the intervertebral foramina, caused by the narrowing of the foramina and exaggerated, in those cases with backward displacement, by the encroachment of the lower posterior border of the fifth lumbar vertebra. Subluxation of the facets, as discussed by Scott in degenerative disc disease, also plays a role in the production of symptoms (Figs. 5-A, 5-B, and 6).

The differentiation of disc herniation from degenerative disc disease is obviously of great therapeutic importance because, in disc disease, there is no herniated material to remove for the purpose of alleviating pressure on the nerve roots. This explains in great part the poor results after surgery. Instead, it would seem logical, in the presence of disc disease and actual backward displacement, to fuse the lumbosacral joint, with the lumbosacral junction in hyperflexion, in order to reduce the vertebral slipping as much as possible, and to improve the width of the intervertebral foramina.

When the roentgenologist finds a malalignment of the fifth lumbar with the first sacral vertebra, the lower border of the fifth lumbar and the upper border of the first sacral, as well as the amount of malalignment, should be measured. If the malalignment exceeds the difference in diameters, there is actual backward displacement. Careful scrutiny of the apophyseal joints shows overriding of the facets and, eventually, impingement upon the pedicles or laminae. A narrowing of the posterior aspect of the lumbosacral disc is commonly found and its significance is controversial; but, when associated with signs of instability, it can be inferred that degenerative changes are taking place.

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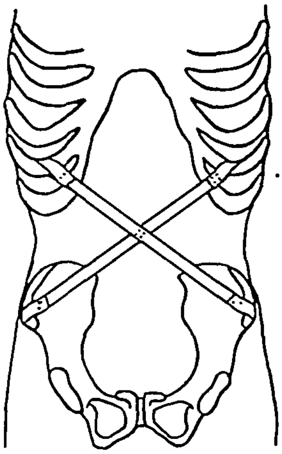

FIG. 5

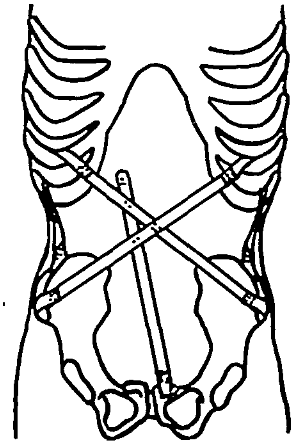

FIG. 6

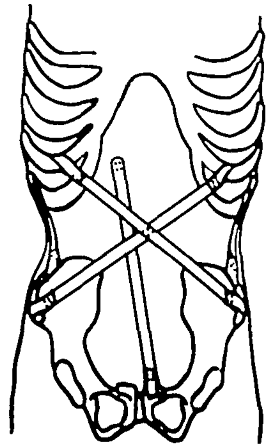

FIG. 7

Fig. 5: CASE 5. Muscle status and fascial repair.

Right		*Left*
2	Quadratus lumborum	1
4	Serratus anterior	4
2	Erector spinae	2
0	Upper rectus abdominis	0
0	Lower rectus abdominis	0
0	Upper obliquus abdominis	0
0	Lower obliquus abdominis	0
4	Upper extremities	4
0	Lower extremities	0

This patient is to have fascial straps for quadratus lumborum and recti.

Fig. 6: CASE 6. Muscle status and fascial repair.

Right		*Left*
0	Quadratus lumborum	0
3	Serratus anterior	3
2	Erector spinae	2
2	Upper rectus abdominis	0
0	Lower rectus abdominis	0
2	Upper obliquus abdominis	0
0	Lower obliquus abdominis	0
3	Upper extremities	3
0	Lower extremities	0

Fig. 7: CASE 7. Muscle status and fascial repair.

Right		*Left*
0	Quadratus lumborum	0
4	Serratus anterior	4
3	Erector spinae	3
2	Upper rectus abdominis	2
0	Lower rectus abdominis	0
0	Upper obliquus abdominis	2
0	Lower obliquus abdominis	0
4	Upper extremities	4
0	Lower extremities	0

If the patient is fortunate enough to have some muscle power in the abdominal wall, hether in the upper or the lower quadrants, every attempt should be made to utilize this ower; and the straps of fascia should be connected by fascial tunnels from the intact uscle to the bone insertion. When no muscle strength is present, bone-to-bone attachents are used. In any instance wherein bone is used, the tunnel should be covered by a m bridge of bone. For example, in the ilium an adequate bridge of bone should be present n top of the tunnel to anchor the fascial straps firmly. If good bony anchorage is obtained, physical therapy in the form of rather rigorous underwater exercises can be engaged in with impunity at an early date postoperatively. The most difficult area in which to make a good bone tunnel is the superior ramus of the pubic bone just lateral to the symphysis. A rete of veins is encountered in this area, which, if damaged, may allow blood to collect between the fascial spaces and cause difficulty. Care must be taken, so that damage will not be done to the structures of the inguinal canal.

We have been very liberal with the amount of fascia employed. Previous authors have mentioned that nine-inch straps are sufficiently long to be used as fascial transplants. This is true for the transplants used laterally in the mid-axillary line from the tenth ribs to the crests of the ilia. In all of our cases, however, the cross straps and the anterior strap have had to be from twelve to fourteen inches in length in order to reach satisfactorily the distances required. It is necessary to bring the fascia through the osteoperiosteal tunnels and double the ends back onto themselves before suturing. Moreover, from the cases herein

THE PERIPHERAL DISEASE OF POLIOMYELITIS

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Considerable doubt has arisen that the peripheral symptoms of poliomyelitis can be satisfactorily or wholly explained on the basis of the observed pathological process in the nervous system. From clinical studies, there is reason to suspect, in addition, that the disease directly assaults the peripheral tissues of the body. So devastating are the eventual changes in the peripheral structures, and so damaging to locomotion, that it is most necessary to consider every possible origin of such effects and to ascertain the means by which these local changes take place, in order that effective preventive measures may be utilized.

By comparison with the voluminous reported studies of the disease in the nervous system, the peripheral tissues have been practically neglected. The studies of Carey and his associates [1] indicate that motor-nerve endings in muscle may be primarily affected. Knowledge that tissue of the central nervous system has a favorable attraction for the virus of poliomyelitis has beguiled most investigators from serious consideration of the disease process directly affecting the peripheral tissues.

The dearth of objective findings in the peripheral tissues, reported in the literature, does not necessarily prove an absence of primary changes in these parts. It is entirely possible that the methods of study of tissues are still not sufficiently precise to detect changes due to poliomyelitis in these particular tissues. Changes in the skin and muscles escape the pathologist, unless the variations due to pathological changes are remarkable.

Poliomyelitis has long been considered to be a disease basically affecting the central nervous system, with the principal lesion in the spinal cord. Study of the disease has largely been centered about the most easily observed symptom,—weakness or paralysis of the skeletal muscles. Extensive laboratory studies of the disease processes leave little doubt that destruction of anterior-horn cells of the spinal cord may occur, and that permanent motor denervation with paralysis of the correlated muscle units of the body is inescapable in such a case.

Changes in the peripheral tissues have been thought to be entirely dependent upon, and secondary to, the disease in the spinal cord. Not only paresis, but also atrophy, contractures, joint stiffness, leg shortening, circulatory and trophic changes, deformities, and other sequelae were considered to be an unavoidable aftermath of the disease. The spinal cord is relatively inaccessible and its affection unresponsive to any form of therapy known at present.

From a knowledge of anatomy and of the pathology of the nervous system in poliomyelitis, the outlook was definitely not hopeful. As one author recently summed up the situation: "About the only thing that can be done is to let it run its course and then try to patch up the damage".

Based upon the concept that the principal lesion of poliomyelitis is an affection of the central nervous system, the most conscientious efforts in treatment have not prevented a fearful toll of crippled and deformed victims. Poliomyelitis remains the leading single cause of crippling of children in the United States today. It is, therefore, of importance to set down clinical observations upon which possible improvement in methods of treatment may be based.

CLINICAL DATA

A recent contribution to our clinical knowledge of poliomyelitis is Miss Kenny's emphasis upon spasm or hypertonicity as a distinct entity. Whereas paralysis is reported

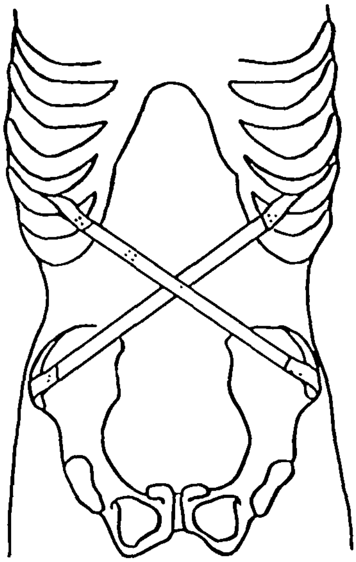

FIG. 8

CASE 8. Muscle status and fascial repair.

Right		Left
4	Quadratus lumborum	4
4	Serratus anterior	4
4	Erector spinae	4
4	Upper rectus abdominis	3
0	Lower rectus abdominis	0
2	Upper obliquus abdominis	2
0	Lower obliquus abdominis	0
4	Upper extremities	4
2	Lower extremities	3

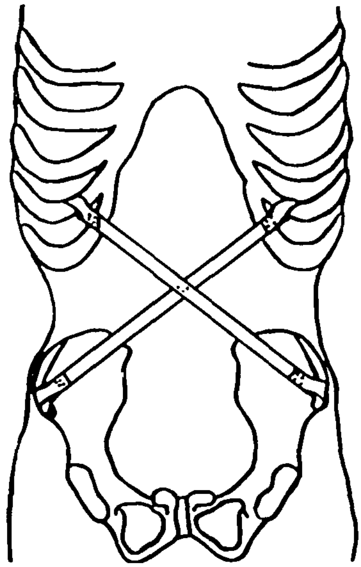

FIG. 9

CASE 9. Muscle status and fascial repair.

Right		Left
3	Quadratus lumborum	3
4	Serratus anterior	4
1	Erector spinae	1
3	Upper rectus abdominis	3
0	Lower rectus abdominis	0
0	Upper obliquus abdominis	0
0	Lower obliquus abdominis	0
4	Upper extremities	4
3	Lower extremities	3

presented, it appears that the broader the strap, the more support will be given to the abdominal wall. We have tried to make our straps of fascia one inch or more in width. In order to obtain such liberal quantities of fascia, a separate operating team is employed. Removal of the fascia is performed under direct vision, a long incision being made posterolaterally on the thigh from just below the trochanteric area to the level of the knee joint. In some cases, it is necessary to remove the superficial fibrous sheath of the tensor fasciae femoris superiorly, in order to get sufficient length. Distally, one has to go as far as the deep fascia of the thigh just above the knee joint. If fascia from only one thigh is needed, selection of the donor thigh is determined by the amount of muscle power present. If there is any difference, the weaker extremity is utilized. When the operation must be done in two stages, fascia from both thighs is required. With such a wide strap of fascia removed, it is believed that to attempt to suture the remaining fascia would only cause pain to the patient. Thus in order to repair the donor fascial site, the subcutaneous tissues are closed with interrupted No. 60 cotton sutures, and fine continuous wire is used for the skin, followed by a pressure dressing.

Concerning the fate of this fascia in its new site, it makes no difference whether a tube is made out of it, or whether it is sutured into place as a flat piece. The fascia very soon rolls upon itself, assuming the shape of a strong cord (Fig. 1-B). When one palpates the fascial transplants months later, they are rope-like, rather than flat.

The table on which the patient is placed during the operative procedure is in a flat position, thus allowing more room for the two operating teams.

Skin incisions are made in line with the cleavage of the skin. These incisions heal easily with minimum scar. A five-inch incision is utilized over the selected rib site; an incision of from three to four inches is adequate for the ilium; and an incision of from four to five inches, made in a circular fashion about the umbilicus, gives excellent exposure for the

FRACTURE-DISLOCATION OF THE THORACOLUMBAR SPINE

With Special Reference to Reduction by Open and Closed Operations*

BY J. KENNETH STANGER, F.R.C.S., NEWCASTLE-UPON-TYNE, ENGLAND

This paper is based upon an analysis of forty-three patients, treated in the Orthopaedic Department of the Royal Victoria Infirmary, Newcastle-upon-Tyne, and in allied hospitals in the district, during a period of approximately six years.

In the vast coal-mining district of Northumberland and Durham, 137,000 men are employed in the industry. The nature of their work is hazardous, and the large majority of the patients with industrial injuries admitted to the hospitals are pitmen. Injuries to the spine occur relatively frequently, and the pitman and his family have come to dread the term "fractured spine", bringing with it, as it does, the vision of permanent paralysis and of a life which is truly worse than death. Of course, not all fractured spines are fracture-dislocations, nor are the latter invariably associated with complete paraplegia. The psychological association remains, however; and this may, in part, account for the high rate of incapacity among miners who have sustained compression fractures, fractures of transverse processes, and other less severe injuries.

The seams in these coal fields are low,—two feet is considered an average; the lowest is eighteen inches. The pitman works, crouching in a confined space; the roof constantly shifts or settles; and "falls of stone" or of "roof" are relatively frequent. If crushed by such a fall while lying, any variety of injury may occur. If sitting in a crouched position, the shoulders are forced forward and downward, causing excessive flexion of the trunk and spine, and resulting in anything from a compression fracture of a vertebral body to a complete fracture-dislocation with paraplegia. In hyperflexion of the spine, the relatively fragile vertebral body is compressed by the body above it, so that a hinge action occurs at the intervertebral articulations. If the force is continued, the interspinous and intervertebral ligaments, and possibly the disc, are ruptured; and dislocation of the intervertebral articulations occurs, so that the upper vertebral body moves forward on the lower. It is then that pressure on, or section of, the spinal cord may occur. The lower articular processes of the vertebra above may be transposed to the front of the upper processes of the vertebra below, so that they become locked in luxation and the dislocation cannot be reduced spontaneously. One or more of these processes may be fractured.

INDICATIONS FOR OPERATION

It has been thought that the paraplegia which complicates fracture-dislocation might be due to:

1. Section of the cord, in which case it is incurable;
2. Pressure on, or stretching of, the cord, without section;
3. Hematomyelia or oedema.

It seems doubtful whether so-called spinal shock ever occurs.

If the paraplegia is due to pressure, hemorrhage, or oedema, and therefore remediable, it is reasonable to assume that recovery might be expedited by the reduction of the displacement and the relief of the pressure. The question arises of how one can estimate the cause or degree of trauma to the cord. Unless the paraplegia is partial, it is impossible to tell on neurological grounds alone whether or not there has been a complete severance of the cord; and, as will be shown later, gross bone displacement, if in injuries of the lower lumbar spine, does not necessarily indicate gross cord damage. A further indication for

* Read at the Spring Meeting of The British Orthopaedic Association, Newcastle-upon-Tyne, May 1946.

reduction, even in cases of fracture-dislocation without paraplegia, would appear to be the complete correction of the skeletal lesion, so that a maximum recovery of function is achieved. In a large proportion of the patients in the present series, therefore, open or closed reduction has been attempted; and a critical analysis of the results is presented. The series is certainly not great enough to justify any definite conclusions on statistical grounds; but certain general impressions are gained, and a few of the cases are worthy of

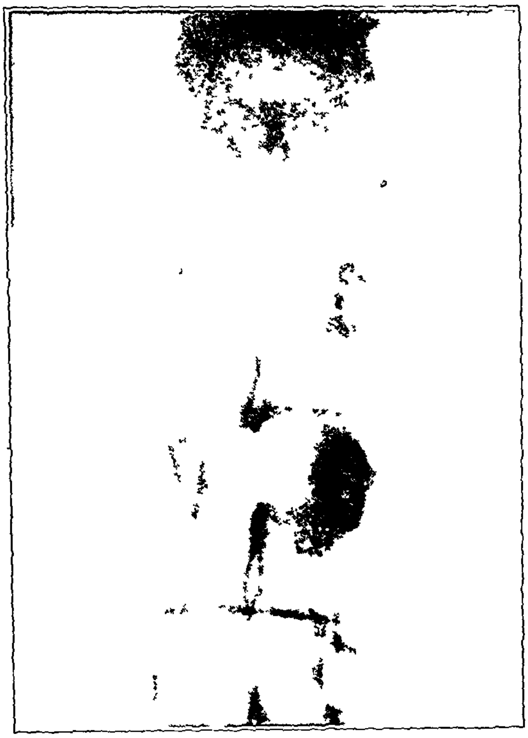

FIG. 1-A

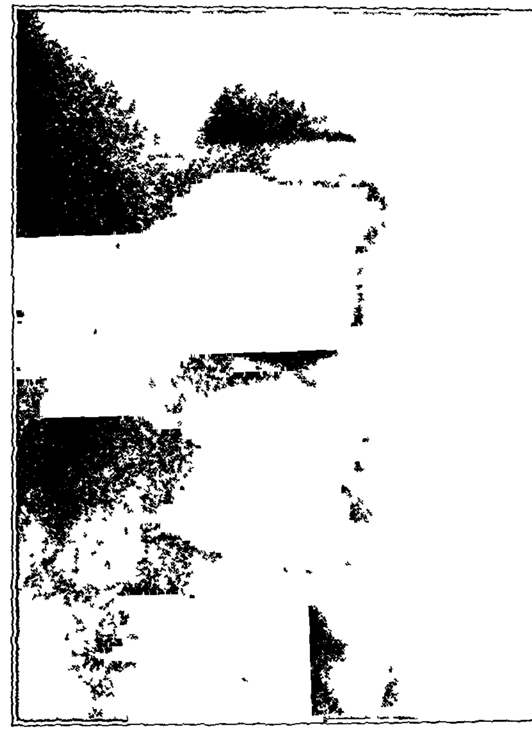

FIG. 1-B

Case 1, G. B. This patient had a fracture-dislocation between the twelfth thoracic and the first lumbar vertebrae, with *interlocking of the articular facets.*

Figs. 1-A and 1-B. Before reduction.

FIG. 1-C

FIG. 1-D

Immediately after reduction.

work about the anterior abdominal wall. The lumbar spine is acutely flexed by placing the operating table in a V position, when the operator is ready to anchor the straps. In this way, the fascial straps are anchored with No. 9 cotton sutures as tightly as possible. The more tension that can be placed on these fascial straps, the easier it will be for them to perform their function (Fig. 4-B). The only exception to this rule is when the erector spinae are weak. It is unwise to deprive the patient of all of his lumbar lordosis, which he may need in balancing activities. In this event, the straps are anchored snugly, but the lumbar spine is not flexed to such an acute degree. After closure of the abdominal wounds with interrupted No. 60 cotton subcutaneously and continuous wire for the skin, the patient's bed is brought to the operating room, placed in a V position, and the patient is lifted from the table to the bed without allowing any stress to be placed upon the fascial grafts.

Postoperative Care

As soon as the anaesthesia has worn off, the patient is encouraged to cough several times hourly, in an attempt to prevent any pulmonary complications. A pulmonary atelectasis developed in one of our patients (Case 5), but with conservative measures, such as voluntary coughing on the part of the patient and the use of an oxygen tent, he progressed very satisfactorily. No other complications have been noticed in this series.

The following day, a graduate physical therapist resumes bed therapy to the extremities, in order to prevent any contractures from developing during the three weeks in bed. After three weeks of the V position in bed, the stitches having been removed, the patient is transported on a litter to the pool. The flexion of the lumbar spine is maintained by having the patient lie on his side. Underwater therapeutic exercises are begun. After the patient is in the pool, he lies on the plinth, and then tries wig-wag and trunk-rolling exercises with progressive intensity. The buoyancy of the water helps to relieve the weight of the lower legs on the fascial straps, while these exercises are being done. During the first few days, the legs are placed in a rubber ring, in order to prevent stress on the new implants. In this way, an increasing amount of work is placed on these fascial straps, which is sufficient to initiate work hypertrophy. Gradually, more and more is done daily in the therapeutic pool. At the end of the six weeks, the nurses on the ward are instructed to lower the foot portion of the bed gradually. In about a week the bed has been restored to its normal position.

At the end of the six weeks, walking exercises are begun. During the convalescent bed period, the patient's braces have been checked thoroughly, so that there will be no delay in resuming walking exercises, when his bed period is finished. A physical therapist, especially trained in walking exercises, is employed for this purpose. The patient slowly accomplishes more and more, as his uninvolved muscles regain their strength, and as the fascial grafts take over more and more of the work intended for them.

RESULTS

The evaluation of improvement from fascial transplantation to the abdomen is difficult. The main reason for this is probably due to the fact that there are such variations of paralytic involvement in patients who have poliomyelitis. No criteria have heretofore been suggested upon which to base improvement from this operation. At this Hospital, we have tried to formulate an accurate method to judge the degree of a patient's improvement postoperatively. During his convalescent period, a patient with severe involvement must undergo a series of complex activities. To a normal individual, these activities are quite simple; but it requires months and even years for the paraplegic and quadriplegic to master such activities. We have selected seventeen different activities which the paralyzed individual must accomplish with some degree of perfection, in order to make himself independent.

We have consolidated into one chart the preoperative and postoperative accomplish-

About fifteen years ago, Dr. John Royal Moore of Philadelphia told me about a small series of patients with congenital club-foot in which he had transplanted the anterior tibial tendon to the lateral border of the foot. He found that it threw the foot out of balance, as time went on, and that he had to put it back in place in a large proportion of cases. He abandoned the operation without publishing the results.

In the short period of five years, Dr. Garceau and Dr. Manning have had to put two back, and they say a third child needs it. Many more may need it before the growth period has been completed.

My suggestion is that we all spend time and thought on how to improve our plaster technique. We will then have the satisfaction of knowing that we have done no harm to the foot. We will see club-footed children go into life with more flexible and useful feet, and with fewer adhesions and scars.

Dr. Charles W. Peabody, Detroit, Michigan: Dr. Garceau has made an excellent presentation of his treatment in this paper, and I am sufficiently acquainted with his work and character to give major consideration to any observations and conclusions he makes. I have also seen the results in some of his cases.

I appreciate his calling upon me to participate in the discussion, and I believe I know his reason. Some fifteen or more years ago, I presented, at an Association Meeting, a paper which involved a study of congenital metatarsus varus. This paper included an operative observation of an instance of this deformity where the anterior tibial tendon lacked any normal bony insertion.

Subsequently, I found the same anomaly in a recurrent club foot, which remained corrected after such tendon transposition. So, I believe the possibility of such an anomaly must be considered in the treatment of either type of congenital foot deformity.

Furthermore, I have long stressed not only the influence of muscle imbalance in producing foot deformities, but also the necessity of balanced redistribution, no matter what else is done.

I have also held to the theory that talipes equinovarus results from a prenatal muscle imbalance, due to an imperfect development of pronator and extensor function. I am convinced that often a permanent residual insufficiency prevails in the three peronei, and that, when this can be demonstrated in the recurrent cases, transposition of the anterior tibial tendon is indicated. However, I believe it is always difficult and usually unnecessary to make the shift as far out as Dr. Garceau does; for if the skeletal deformity is adequately corrected, mid-foot transposition is enough and reversed imbalance is more likely to be avoided.

Now, in case Dr. Garceau does not do so in closing, I want to further stress the absolute necessity for complete overcorrection and maintenance of it until functional recovery of the evertors, with total muscle balance, has had opportunity to occur. With any persistence at all of either supination or of forefoot varus, the different fulcrum points in the foot are so far off their dead center that one set of muscles works at an enhanced advantage and the other at a major mechanical disadvantage.

Dr. Eben W. Fiske, Pittsburgh, Pennsylvania: Over thirty years ago, I came out with a very definite stand on the conservative treatment of club-foot. It was nothing new then; the doctors all knew it, but for some reason they had constantly forgotten it. In the Children's Hospital at Boston, we had a series of early cases in which operation was performed. I had the opportunity to watch what happened to these patients, as compared to those who were treated conservatively. We developed a technique of conservative treatment with no attempt at operative treatment and without any cutting, any anaesthetic, or any stretching. Not only were the results better, but they remained better. To me the key to the whole matter was the absence of trauma. It is not a matter of re-establishing bones and joints, it is a question of not traumatizing the bones or joint surfaces, or the vessels and nerves. I still believe that one of the important features in the successful treatment of club-foot is that we should carefully treat these cases without any force or trauma. When we do that, we will have preserved all the tissues in the foot, and we will be able to restore them to normal, and have the functional result that we should have.

I am interested in Dr. Kite's method, but I have had little experience with it, because I like my own. I feel that, if we mold these feet without trauma and do it often enough, we will get a result. As Dr. Kite stressed, the foot itself must be corrected by abduction and eversion first. Complete overcorrection will result in a foot that will function properly. The muscle balance will correct itself, and we will have no worry about tendon transplantation.

Dr. George J. Garceau, Indianapolis, Indiana (closing): I wonder what Dr. Kite does with the 10 per cent. of cases which he reports unsatisfactory? This operation was performed on 6.7 per cent. in our series of 1,275 patients. In discussing bone-cutting operations for recurrent club feet, Dr. Kite says, "If the feet should relapse, the same operation can be done again, removing a little more bone where necessary, and a successful correction obtained". We have done anterior tendon transposition rather than a bone-cutting operation. We have had to restore the anterior tibial tendon to its former natural insertion, but I can see no objection to this. It is a small price for obtaining a good weight-bearing foot.

This operation is resorted to only when recurrence of the deformity cannot be prevented and the indication of muscle imbalance is present.

IMPROVEMENT RECORD CHART

Case	1	2	3	4	5	6	7	8	9
Age of Patient	30	44	23	22	25	21	22	33	24
Duration of Disease Prior to Transplantation (Months)	26	31	16	6	24	19	9	23	22
Duration of Disease Since Transplantation (Months)	10	9	8	5	4	4	2	3	2
Number of Operative Procedures	1	1	1	2	1	2	2	1	1
Ability to Roll over in Bed	Grade III	Grade III	Grade III	Grade III	Grade II	Grade III	Grade O-b	Grade II	Grade I
Ability to Sit up in Bed	Grade III	Grade III	Grade III	Grade II	Grade II	Grade III	Grade IV	Grade III	Grade O-b
Ability to Get into and out of Braces	Grade III	Grade III	Grade III	Grade III	Grade II	Grade O-b	Grade IV	Grade I	Grade O-a
Ability to Get into and out of Wheel Chair	Grade II	Grade IV	Grade III	Grade III	Grade II	Grade III	Grade O-b	Grade I	Grade II
Ability to Get into and out of Straight Chair	Grade IV	Grade II	Grade III	Grade II	Grade I	Grade O-a	Grade IV	Grade O-b	Grade II
Ability to Dress and Undress	Grade O-b	Grade II	Grade III	Grade III	Grade II	Grade II	Grade I	Grade II	Grade O-b
Ability to Walk in Pool	Grade III	Grade II	Grade III	Grade III	Grade II	Grade IV	Grade IV	Grade III	Grade II
Ability to Walk in Parallel Bars	Grade III	Grade III	Grade III	Grade III	Grade II	Grade O-b	Grade II	Grade II	Grade II
Ability to Walk in Walker	Grade III	Grade III	Grade III	Grade III	Grade II	Grade IV	Grade III	Grade II	Grade III
Ability to Walk with Crutches—Four Point Gait	Grade IV	Grade III	Grade III	Grade III	Grade II	Grade O-a	Grade IV	Grade III	Grade III
Ability to Walk with Glider Canes	Grade IV	Grade III	Grade O-a	Grade O-a	Grade I	Grade O-a	Grade IV	Grade IV	Grade O-a
Ability to Walk with Canes	Grade O-a	Grade O-a	Grade O-a	Grade IV	Grade O-a	Grade O-a	Grade O-a	Grade IV	Grade O-a
Ability to Walk Three-Inch Steps with Rail	Grade IV	Grade IV	Grade III	Grade IV	Grade O-a	Grade O-a	Grade IV	Grade II	Grade O-a
Ability to Recover Objects from Floor	Grade III	Grade III	Grade III	Grade II	Grade I	Grade O-a	Grade IV	Grade O-b	Grade II
Ability to Get onto and off Commode	Grade IV	Grade IV	Grade IV	Grade IV	Grade III	Grade I	Grade IV	Grade II	Grade I
Improvement of Bowel Function	Grade III	Grade III	Grade O-b	Grade O-b	Grade O-b	Grade O-b	Grade O-b	Grade O-b	Grade II
Balance	Grade III	Grade III	Grade IV	Grade III	Grade IV	Grade III	Grade III	Grade III	Grade III

Grade O-a: Patient could not perform activity before or after surgery.
Grade O-b: Patient could perform activity before surgery, and noted no improvement after surgery.
Grade I: Mild improvement.
Grade II. Moderate improvement.
Grade III: Marked improvement.
Grade IV: Patient could perform activity after surgery, which he could not perform before surgery.

INTERTROCHANTERIC FRACTURES OF THE FEMUR

A Survey of Treatment in Traction and by Internal Fixation*

BY MATHER CLEVELAND, M.D., DAVID M. BOSWORTH, M.D., AND FREDERICK R. THOMPSON, M.D., NEW YORK, N. Y.

From the Orthopaedic Service of St. Luke's Hospital, New York City

This survey of 133 consecutive cases of intertrochanteric fracture of the femur, from the Orthopaedic Service of St. Luke's Hospital, includes follow-up studies in 94 per cent. of the cases. In only seven patients, all from the group treated conservatively, is the final outcome not known. The final outcome of all patients treated by internal fixation is known, and recently they have been examined by the authors for the purposes of this study. The series consists of (1) a group of thirty-eight cases treated mainly by traction, and (2) a group of ninety-five consecutive cases treated by internal fixation. The period of study extends from August 1938 until January 1947. During the first three years, treatment was by traction, usually of the Russell type, although two cases were treated with well-leg traction and one with skeletal traction through the lower end of the femur. This survey is an endeavor to compare the results among those patients treated by internal fixation with the results among those upon whom traction was employed.

AGE AND SEX

These patients were elderly, with average ages from twelve to fifteen years higher than those previously reported with intracapsular fractures.[1] Patients treated with traction had an average age of seventy-eight years, while those treated with nail fixation had an average age of seventy-five years. Over half the patients in each group were in the eighth and ninth decades of life. They had, therefore, but a few years of life expectancy. Those who survived for several years were usually in the younger age group,—the seventh decade or younger (Table I).

The sex incidence in the two groups shows that 90 per cent. were women. The preponderance of female patients is probably explained by their less rugged bony structure, and usually more pronounced atrophic osseous changes. Actuarial statistics from a large insurance company show that, at the age of seventy-five, there are 108.9 females alive to every 100 males. In other words, only about 9 per cent. more women are alive at that age than men. Our ratio of fractures in women as compared with those in men, however, was 9 to 1. This should be compared with another group reported from this Hospital [1, 2], with fractures of the neck of the femur, in which the ratio of women to men was 4 to 1. There must, therefore, be some definite cause for the higher female incidence, such as that just mentioned.

RACE

In this series of patients, there has been no instance of a negro patient with a trochanteric fracture. This is so despite the fact that St. Luke's Hospital lies close to the Harlem district of New York City. Such cases do occur, since they are encountered occasionally by one of the authors in another city institution, but apparently they are not so common among aged negroes as among aged whites. The more rugged skeletal frame of the negro may be the reason.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1947.

work about the anterior abdominal wall. The lumbar spine is acutely flexed by placing the operating table in a V position, when the operator is ready to anchor the straps. In this way, the fascial straps are anchored with No. 9 cotton sutures as tightly as possible. The more tension that can be placed on these fascial straps, the easier it will be for them to perform their function (Fig. 4-B). The only exception to this rule is when the erector spinae are weak. It is unwise to deprive the patient of all of his lumbar lordosis, which he may need in balancing activities. In this event, the straps are anchored snugly, but the lumbar spine is not flexed to such an acute degree. After closure of the abdominal wounds with interrupted No. 60 cotton subcutaneously and continuous wire for the skin, the patient's bed is brought to the operating room, placed in a V position, and the patient is lifted from the table to the bed without allowing any stress to be placed upon the fascial grafts.

Postoperative Care

As soon as the anaesthesia has worn off, the patient is encouraged to cough several times hourly, in an attempt to prevent any pulmonary complications. A pulmonary atelectasis developed in one of our patients (Case 5), but with conservative measures, such as voluntary coughing on the part of the patient and the use of an oxygen tent, he progressed very satisfactorily. No other complications have been noticed in this series.

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RESULTS

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We have consolidated into one chart the preoperative and postoperative accomplish-

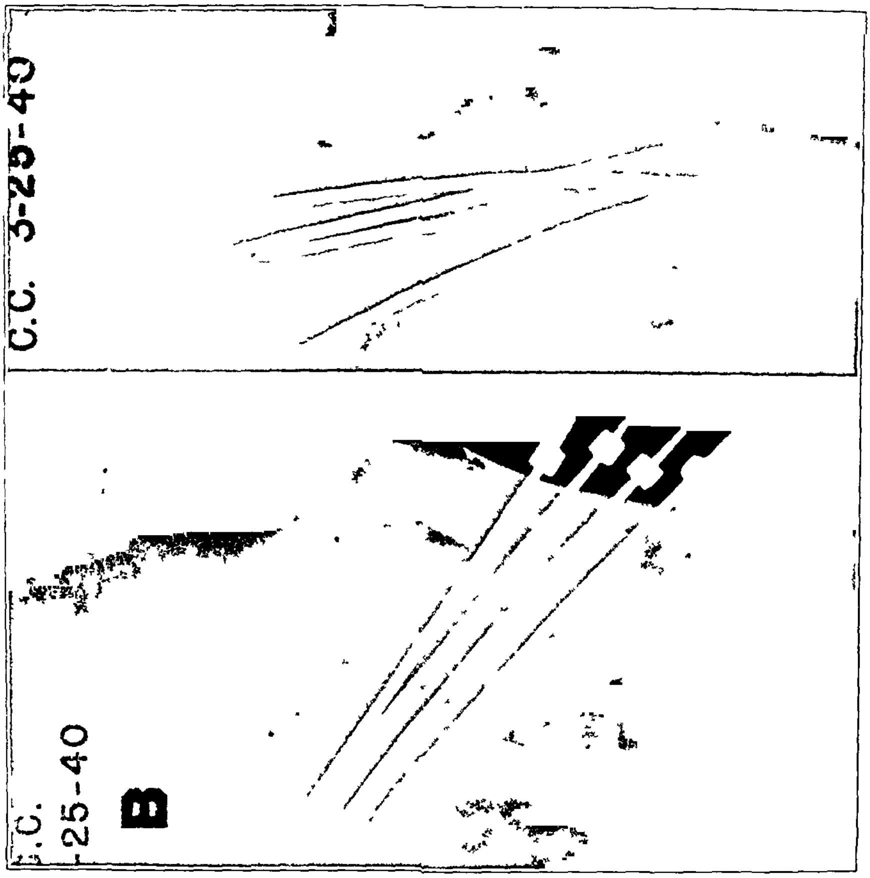

Fig. 1-B

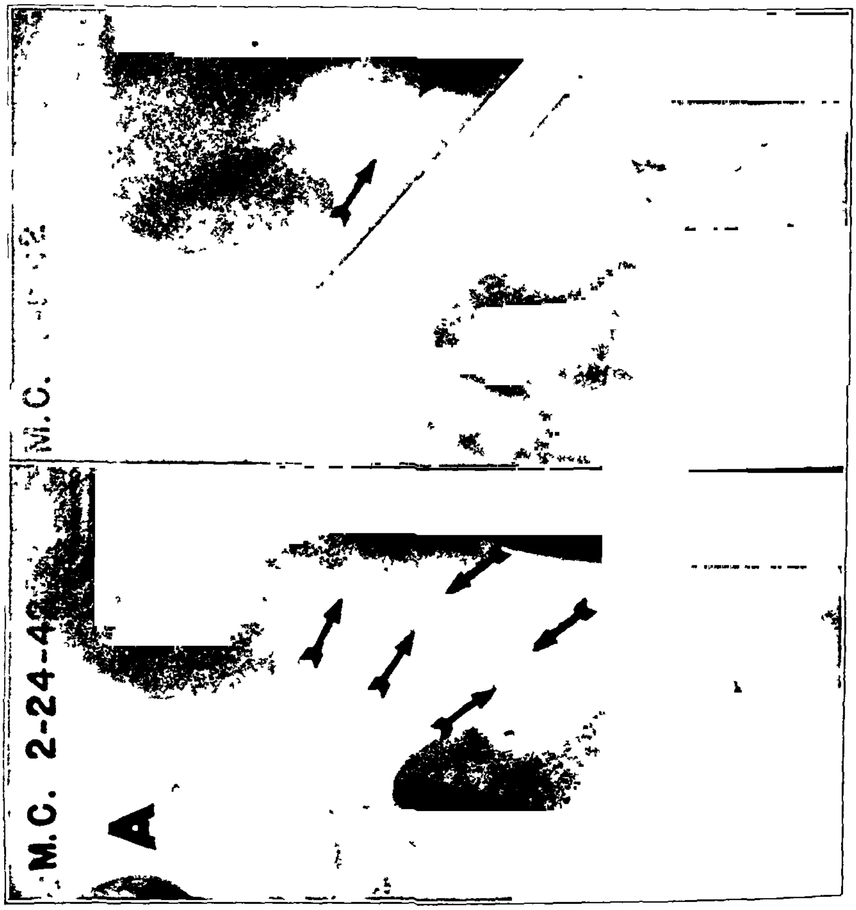

Fig. 1-A

Fig. 1-A: Use of a Smith-Petersen nail in the simplest type of fracture may secure a good result, but it is apt to prove ineffective
Fig 1-B. The use of multiple threaded wire is inefficient, and complicates the operative procedure.

The second physical function in which all patients have shown improvement is walking. We have subdivided this into ability to walk (a) in the therapeutic pool, (b) with parallel bars, (c) in a walker, and (d) with crutches. Only one of the patients failed to notice improvement in the use of crutches, and he was very severely paralyzed (quadriplegic). He was unable to walk with crutches before the procedure, and four months after the operation this activity was still impossible, and he has, therefore, been graded Grade O-a (Case 6). However, it will be noticed in this case that the patient is now able to walk in the walker, which was impossible prior to surgery. After he has walked long enough to develop sufficient strength in his upper extremities to hold his weight, the patient will undoubtedly be able to walk with crutches. Of the remainder of the patients, two who could not walk with crutches preoperatively are now able to do so, and five have shown a striking degree of improvement in walking with crutches. These patients are placed in the Grade III group. One patient (Case 5) has noticed a Grade II improvement; however, this patient has had only the first-stage operation (cross straps) (Fig. 5), but it is apparent that he will need the second stage for his weak quadratus and recti, in order to gain maximum improvement from fascial transplantation. Three of our patients have been able to walk with glider canes, which they were unable to do prior to the operative procedure. One of them has shown a Grade III, and one a Grade I improvement, with respect to this activity. Four of the patients were not able to use glider canes prior to surgery, and have not been able to use them since surgery. They have, therefore, been placed in Grade O-a. Two of the patients, who needed crutches preoperatively, were able to walk with ordinary canes for the first time after the operation. The remaining seven patients have been unable to use ordinary canes either before or after surgery; and therefore, they are placed in Grade O-a.

One very important improvement which we have observed in all of the patients has been the ability to get on and off a commode. If these patients with severe involvement can handle themselves adequately without assistance in this particular activity alone, we believe that this surgical procedure is well warranted. In our group of patients, five are now able to accomplish this routine without assistance; whereas, before operation, it was impossible. One patient has noticed Grade III improvement, one has noticed Grade II improvement, and two have noticed Grade I improvement, with regard to the use of the commode. Strangely enough, two of our patients no longer show constipation as they did prior to surgery. There was no change in the bladder function, in so far as we could ascertain.

Concerning the ability to get in and out of their braces, seven patients have noticed improvement,—one Grade IV, four Grade III, one Grade II, and one Grade I. One has noticed no change,—that is, he could not do it before and he cannot do it now. This individual has a back brace attached to two long leg braces, and has complete paralysis of both lower legs. The other patient (Case 9) who is in Grade O-a was not graded in this particular activity, since he does not use braces. All of the patients except one have noticed improvement in being able to sit up in bed. Similarly, all except one have noticed improvement in being able to roll over in bed. That one (Case 7) falls into Grade O-b, because he could do it with equal agility before surgery. Eight of the patients have noticed improvement in being able to get into and out of a wheel chair. Only one patient has noticed no change. Seven patients have noticed improvement in their ability to get into and out of a straight chair. One of the other two falls into Grade O-b, and the other into Grade O-a.

Four patients have had sufficient abdominal paralysis to necessitate two surgical procedures, and five have only needed one operative procedure. In Case 5, as mentioned above, only the first or cross-strap procedure has been done; in the near future the second operation will be performed. Owing to the development of pulmonary atelectasis, it was deemed wise to delay the second stage for a few weeks. Usually, however, the second or completion stage is performed three weeks following the first operation.

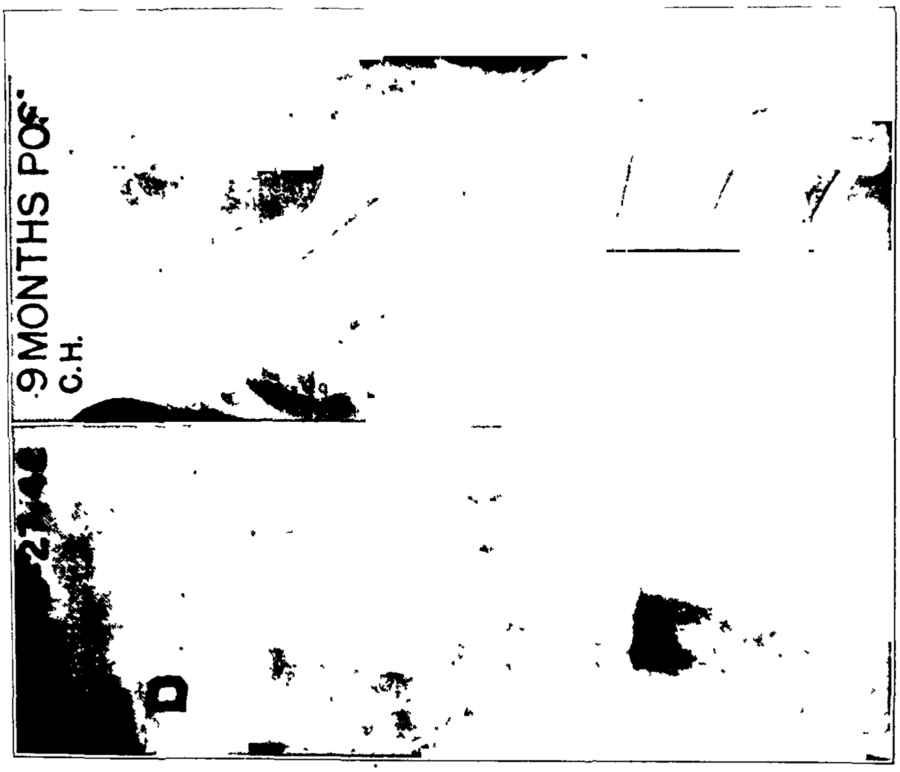

FIG. 1-D

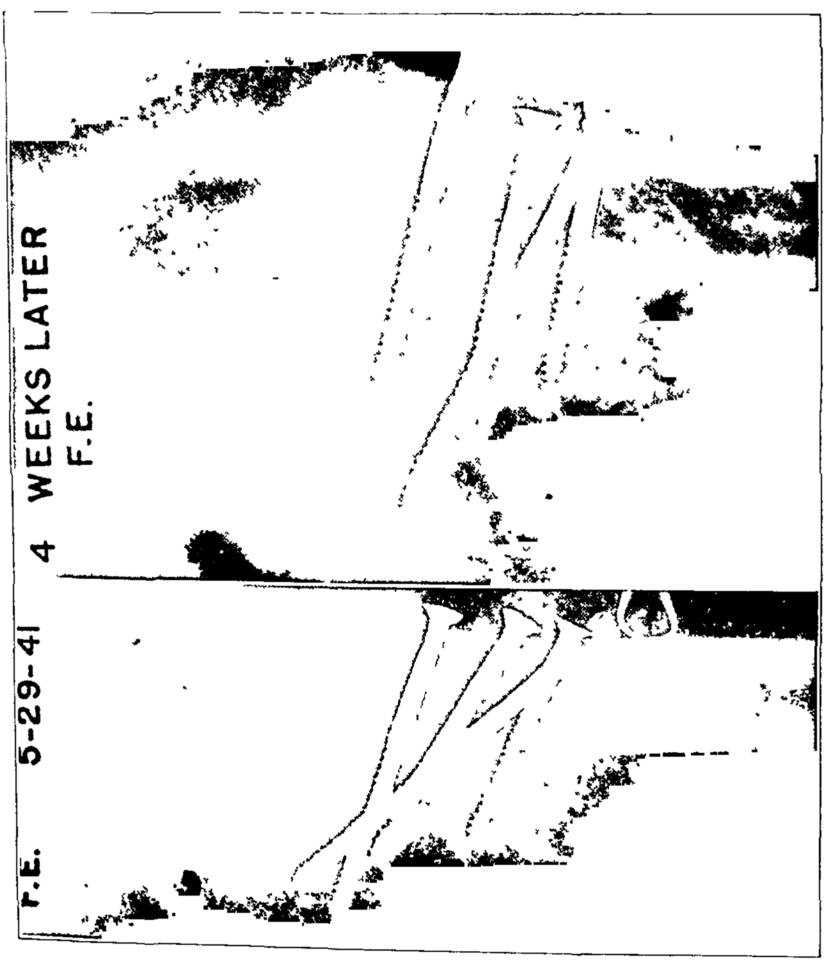

FIG. 1-C

Fig. 1-C: The use of multiple screws secures fixation, but generally fails to prevent coxa vara from developing. The screws may become loosened and wander.

Fig. 1-D: The Thornton nail, when placed, is mechanically weak at the juncture. Such apparatus is more liable to breakage, bending, or loosening of the bolt than is a cast one-piece nail. The methods illustrated in Figs. 1-A, 1-B, and 1-C were tried, but all were discarded.

DISCUSSION

These patients must learn to use their new abdominal support. They must learn how to bring the shoulders back and the thoracic cage up, in order to put maximum tension on the transplanted fascia, and thus bring forward the anterior portion of the pelvis. This action transmits the needed power from the arms, shoulders, and chest to the lower legs through the fascial straps. It takes a considerable length of time to learn how to do this and, of course, depends upon the amount of shoulder and chest involvement present.

It should also be mentioned that, in grading these patients, no attempt has been made to compare them to normal individuals. We cannot grade the results of this operation in terms of normalcy. For the most part, the activities mentioned are not activities in which the unafflicted individual must engage. The actions of a patient who has noticed a striking improvement, due to fascial transplantation, cannot be compared to those of a normal individual in performing the same functions, because the latter does not possess paralyzed extremities. When the nerve supply to the abdominal muscles is no longer intact, nothing will replace normal muscle action, but the fascial transplants do suspend the pelvis anteriorly and laterally in such a way as to assist these patients in making a physical adjustment to life. Furthermore, this method of grading allows ample room for further improvement in these individuals.

It might be considered by some orthopaedic surgeons that inadequate time has elapsed for the use of this procedure in some of these patients,—as those who have had the disease for less than two years. In fact, many authors who have written on the reconstructive stage of infantile paralysis have stated that in the first two years, surgery plays little or no role. We do not feel that this is true, especially in cases of abdominal transplantation. Three of our patients (Cases 1, 2, and 3) had had residual paralysis for two years or longer. No improvement had been noted in the strength of the paralyzed abdominal wall for twelve months or more. We now feel, in retrospect, that progress in these cases was hindered by waiting the additional year or more before surgery was suggested. If it is determined by the surgeon in charge and the physical therapist that the patient has shown no improvement in the strength of the abdominal muscles for a period of three months, it is our belief that this type of reconstructive surgery is indicated. There are many reasons for this belief. If the surgery enables the patient to engage more actively in those functions which are pertinent to his rehabilitation, it allows the patient to develop the muscles which were not involved *per se* in the initial onset of his disease. The atrophy of these muscles is secondary to the bed rest or inactivity, which is brought about by his inability to use his paralyzed abdominal wall or the muscles which elevate the hip in walking and other activities. Several of our patients, for example, were unable to walk with crutches, because of weakness in the arms bilaterally, and also because of failure of the abdominal muscles to connect the trunk with the pelvis. These patients have noticed that since their pelvic suspension surgery they are able to use the walker, and that their arms are definitely getting stronger. This finding is substantiated by our muscle examinations. Furthermore, we think that, if abdominal transplantation is done early enough—that is, during the first six to eighteen months—the suspension of normal, good, or fair upper recti and internal and external oblique muscles to the pelvis will give them a firm attachment upon which they may act and become stronger. DeLorme has clearly demonstrated the importance of resistance in the development of muscle strength. Due to the support of these fascial struts, there has been some return in strength of the paralyzed muscles. This, although minimal, has been observed by the physical therapist on the muscle-grading chart in some of the cases herein presented. In these latter cases, we feel that the support of the fascial straps in holding in the paralyzed muscles and preventing overstretching helps them to regain all the strength they possibly can. A flaccid abdominal wall simply overstretches the weakened muscles, and makes them lose all the strength they might have gained, had one waited until

LOCATION OF FRACTURE

The authors were prepared to find a preponderance of these lesions on the left side. This was revealed, the frequency being 2 to 1. Of the ninety-five fractures which were nailed, seventy-eight were pertrochanteric; and as a rule they were comminuted. Five were subtrochanteric, really involving only the upper femoral shaft. Three were paratrochanteric, involving the base of the neck, and usually were not comminuted. Of the combined fractures, four involved the base of the neck and the trochanter; three involved the trochanter and the shaft; and two were those fractures usually so difficult to treat,—the combined transcervical and trochanteric fracture.

TABLE I

Grouping of Patients in Relation to Form of Treatment

Age		Method of Treatment	
Decade	Years	Traction	Jewett Nail
Fifth	41 to 50	0	3
Sixth	51 to 60	3	6
Seventh	61 to 70	5	16
Eighth	71 to 80	8	43
Ninth	81 to 90	20	21
Tenth	91 to 100	2	5
Eleventh	101 to 110	0	1
Totals		38	95

ASSOCIATED DISEASES OR PATHOLOGICAL CONDITIONS

These elderly people represented a veritable museum of pathological changes, antedating their trauma. The most serious and most common associated lesions were cardiac, diabetic, and senile mental changes. A number of the patients had not walked prior to the fracture, and of course they never walked thereafter. Comfort and simplicity of treatment plus extension of the expected longevity were all that could be provided. Renal lesions, severe crippling arthritis, syphilis, carcinoma, hemiplegia, and the many afflictions of the aged were seen. Rarely was a "good operative risk", in the general surgical sense, encountered. Despite this, they withstood operative trauma, when the procedure was rapid and attended with careful supportive treatment and anaesthesia, as will be seen.

TYPE OF INJURY PRODUCING THE FRACTURE

The causative injury was often trivial,—a simple fall, tripping over a rug, arising from a chair, or some slight misstep. Some individuals were injured by direct violence. Many, we believe, fractured the bone by a twist, dissolution of continuity occurring before the patient fell to the ground. This mechanism is similar to that causing an intracapsular lesion. The main factor contributing to the injury lies in the elderly person's inherent instability while erect, and in his slow reflex proprioceptive response.

REASONS FOR ATTEMPTING INTERNAL FIXATION

At St. Luke's Hospital, until 1942, the standard treatment for trochanteric fractures, as has been stated, was usually traction. Although this was thought to be eminently satisfactory, a review of the records of these patients has shown a great many complications in the course of their treatment, which were unappreciated at the time. In spite of excellent

the arbitrary two-year convalescent period had elapsed before considering surgery. It is true that a simple abdominal support will hold in the paralyzed muscles, but this is only temporary, and the patient has no support when he rests. An adequate support is one that is present at all times in all positions. We consider this fascia as an internal support for weakened muscles.

It is an error to consider this procedure only if all other efforts fail. It has been noted in this Hospital that, after the first few patients had been operated upon, other patients became aware of the postoperative improvement. Subsequently, some have asked if they too might be candidates for a similar procedure.

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Backward Displacement of Fifth Lumbar Vertebra in Degenerative Disc Disease

BY CAPTAIN GILBERT H. FLETCHER

(*Continued from page 1026*)

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nursing care, pressure sores over the sacrum and buttocks were the rule rather than the exception. Cystitis and bladder complications were frequent. Knees, made stiff from prolonged traction, were difficult to restore to normal. Many patients were left with some residual contracture of the hip or knee. Permanent vascular changes, peroneal-nerve palsies, muscle atrophy, psychoses, prolonged general inanition and debility, and a high mortality were disclosed. In follow-up examinations in the Out-Patient Department, many patients showed a crippling external rotation of the hip, in spite of roentgenographic evidence of apparent reduction of the fracture. Although the patients with badly displaced and comminuted fractures had the worst results, in many of the "simple" cases the outcome was poor. For these reasons, an attempt was made early in 1940 to hold the fracture in good position by some form of internal fixation.

TYPES OF INTERNAL FIXATION

It was found that undisplaced fractures, or those with minimum displacement without extensive comminution, could be held in place successfully with the Smith-Petersen nail (Fig. 1-A). The limb did not have to remain in traction for the long period of time which was necessary without nailing. Straight-nail fixation, however, was applicable to only a few of these undisplaced fractures, and it was apt to fail even there. It was not applicable to the majority of fractures, which were comminuted or displaced. This use of the simple straight nail for trochanteric fractures has been discarded.

Next, threaded pins were used (Fig. 1-B). They, too, were discarded as lacking stability, as unsatisfactory for comminuted fractures, and as unnecessarily complicating the operative procedure.

An attempt was then made to fix the fragments of the comminuted type of fracture in place with several Vitallium screws (Fig. 1-C). This procedure was complicated, needed extensive exposure, and was not successful in preventing coxa vara unless traction was also maintained.

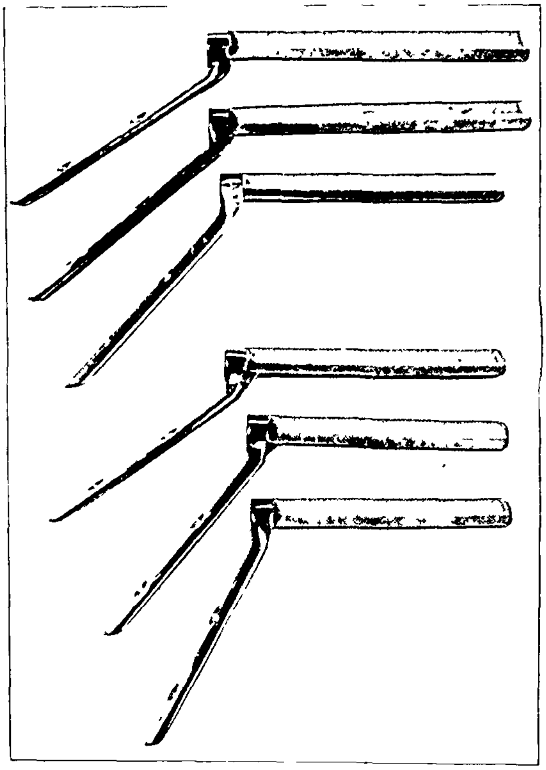

FIG. 2

To handle satisfactorily the various situations encountered, six types of nails are needed. There should be three angles for each nail, and a long and short nail in each angle.

Early in 1942, the Thornton type of combined plate and nail was used (Fig. 1-D). With this appliance, too, although the undisplaced fracture could be held adequately and maintained in proper position, the displaced or comminuted fracture bent into the coxa vara position during subsequent months. This was due to inherent instability at the juncture of the nail and the plate.

The answer to these objections seems to have been found in the angled one-piece nail and plate, described by Jewett in 1941. As the use of this appliance increased, certain situations arose which demanded changes in its structure. The main changes have been as follows: The vertical flange on the deep surface, at the juncture of the plate and the nail, has been removed. This flange caused increased comminution of the trochanteric structure of the femur in several instances as the nail was driven home; and, on several other occasions, increased comminution was due to attempts at cutting a trough for its reception. A passageway for the Kirschner wire, used as a guide, was eliminated. This weakened the

TRANSPOSITION OF THE ANTERIOR TIBIAL TENDON IN THE TREATMENT OF RECURRENT CONGENITAL CLUB-FOOT *

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From the James Whitcomb Riley Hospital for Children, Indiana University School of Medicine, Indianapolis

The incidence of recurrence of the deformity in congenital club-foot is no doubt inversely proportional to the thoroughness of early conservative treatment. Statistics in the literature dealing with this recurrence vary greatly. Brockman reported that 50.6 per cent. of patients with this deformity required no further treatment after adequate conservative management. Kite stated that 90 per cent. of all club feet could be corrected by wedge casts. Blumenfeld, Kaplan, and Hicks recently reported good results in almost 80 per cent. of their patients who had been treated conservatively.

Of 1,275 patients with club-foot, treated in the James Whitcomb Riley Hospital since 1930, eighty-six (6.7 per cent.) have undergone transposition of the anterior tibial tendon. It would appear from our study that recurrence of the deformity, after apparently complete correction, is due to dysfunction of, or incoordination between, the anterior tibial and the posterior tibial muscles, as invertors, and the peroneal muscles as evertors of the foot. In 1894, Sir Robert Jones stated that congenital talipes (equinovarus) is not cured until the patient can voluntarily place the foot in the position of valgus. Therefore, upon examination of recurrent club-foot, we examine the muscle balance. If the peroneal muscles are weak and supination occurs on dorsiflexion (extension) of the foot, we believe that transposition of the anterior tibial tendon is indicated. In 1923, Naughton Dunn mentioned transplantation of the anterior tibial tendon, but did not report on the subject. The operation to transpose the anterior tibial tendon to the lateral aspect of the foot for recurrence of club-foot deformity was first performed by one of us (G.J.G.) in 1933. In 1940, we reported the end results in forty-four patients and fifty-six feet. Since then we have continued to perform the operation whenever indicated. This study is based on the end results in eighty-six patients and 110 feet, and it includes a re-evaluation of the previously reported cases. This operation was chosen, rather than arthrodesis, transtarsal wedge osteotomy, or other bone-cutting operations.

The average age at the time of operation was six and one-half years. The average duration of active preoperative treatment was 4.8 years. The youngest patient was two and one-half years of age, and the oldest, seventeen years, at the time of operation.

One hundred and thirteen operations had been performed previously on the 110 feet, including lengthening of the Achilles tendon (64), fasciotomy (23), Ober's tendon transplantation (2), Brockman's operation (3), triple arthrodesis (5), transtarsal wedge osteotomy (2), decancellation of the calcaneus (6), and capsulotomy (8). Forceful wrenchings had previously been done on many feet. In each instance, the deformity had recurred two or more times.

This operation is not recommended for correction, but rather for prevention of recurrence of the deformity; however, it does have a corrective influence. In two feet, the anterior tibial tendon was returned to its original insertion to prevent planovalgus deformity. It should also have been done in a third case. Many feet continued to improve for a number of years.

Preoperative preparation of the foot by the wedge-cast method is advised. As much correction as possible should be obtained.

The operation itself consists of transposing the anterior tibial tendon to the proximal

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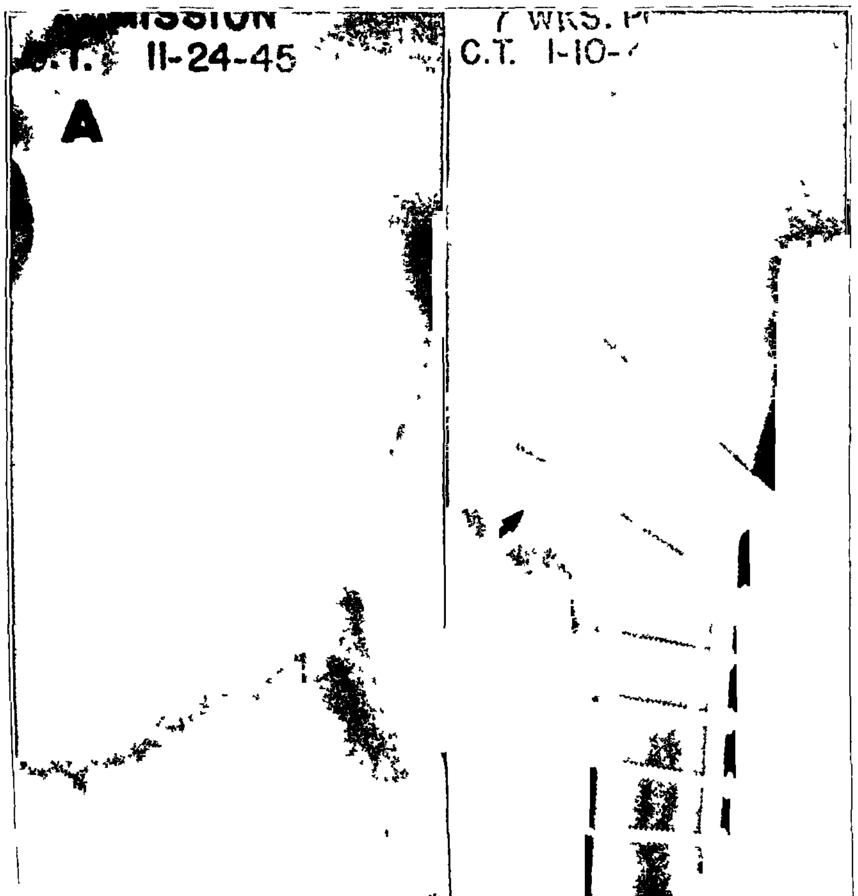

Fig 3-A

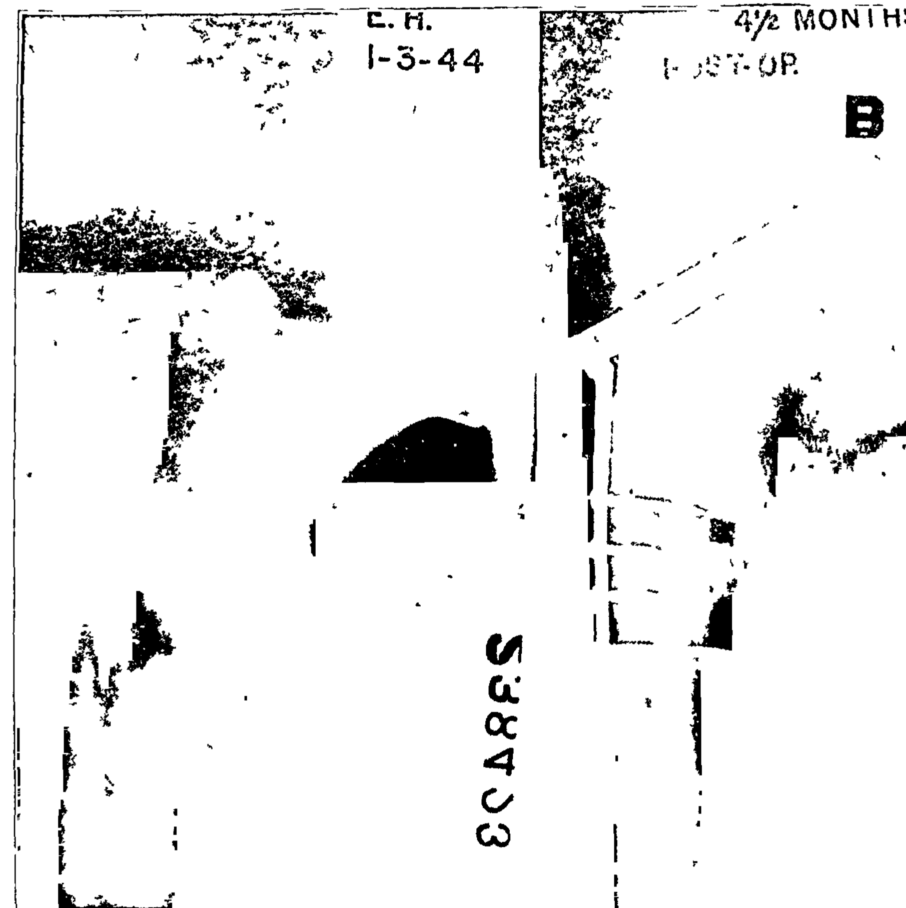

Fig 3-B

Fig 3-A Shows use of the nail in a severely comminuted and displaced fracture Note reassembling of fragments
Fig 3-B Subtrochanteric fracture (really a high-shaft fracture) maintained in position by use of the nail No other method of treatment has been as efficient in this type of fracture.

TABLE I

EFFECT ON THE VARIOUS COMPONENTS OF THE DEFORMITY

	Equinus (*Per cent.*)	Inversion (*Per cent.*)	Adduction (*Per cent.*)
Excellent	64	63	64
Good	21	16	21
Fair	9	14	9
Poor	6	7	6

TABLE II

FUNCTION OF TRANSPOSED ANTERIOR TIBIAL TENDON

	Function (*Per cent.*)	Number of Feet
Excellent	49	54
Good	40	44
Fair	7	8
Poor	4	4
Total		110

end of the fifth metatarsal. If the tendon is too short, it is anchored into the cuboid bone. A cast is worn for at least six weeks after surgery. In most cases, wedge casts are applied every two weeks for two or three months after operation. After discontinuation of the casts, exercises are given to train the transposed anterior tibial tendon.

The effects of the operation on the various components of the deformity are shown in Table I. It is apparent that each component is affected to about the same degree.

The function of the transposed anterior tibial tendon was excellent or good in ninety-eight feet, or 89.1 per cent., of the series.

The end-result study indicates very satisfactory improvement in ninety-one, or 82.7 per cent., of the club feet in the series. In nineteen feet, or 17.3 per cent., the results were not considered satisfactory, although some degree of improvement was noted in each case (Table III). The average period of follow-up was five years. It was over seven years in fifty-six cases.

Twenty-seven operations were performed subsequent to the tendon transpositions.

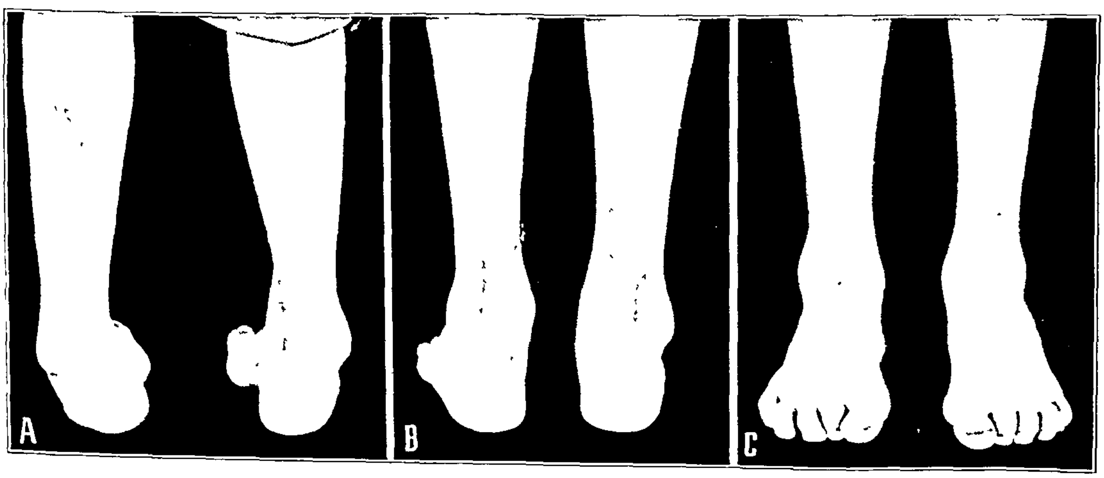

FIG. 1

W. W., aged seven. Recurrence of the deformity in all its components. *B* and *C* are photographs taken three years after anterior tibial transposition, showing excellent correction.

Fig. 3-C

Fig. 3-D

Combined fracture of the trochanter and the intracapsular region of the neck, controlled by an angled nail. Perfect union in both locations resulted.

TABLE III

End Results

	Number of Feet	Percentage
Excellent	67	61
Good	24	22
Fair	9	8
Poor	10	9
Total	110	

One patient tore the tendon at its new insertion, but a good result followed repair. Two tendons were re-anchored to their original insertions with excellent end results. Eight of the ten feet classified as having poor results required bone-cutting operations. The poor results were due to poor correction prior to tendon transposition, rigid feet caused by previous operations, and growth disturbances in the bones of the foot. Poor function of the transposed tendon was a rare cause. In no instance was the operation detrimental.

Frequently, abnormalities were found in the tendons at operation. Separation of the tendon into two or three slips at the insertion was the most frequent finding. Adhesions

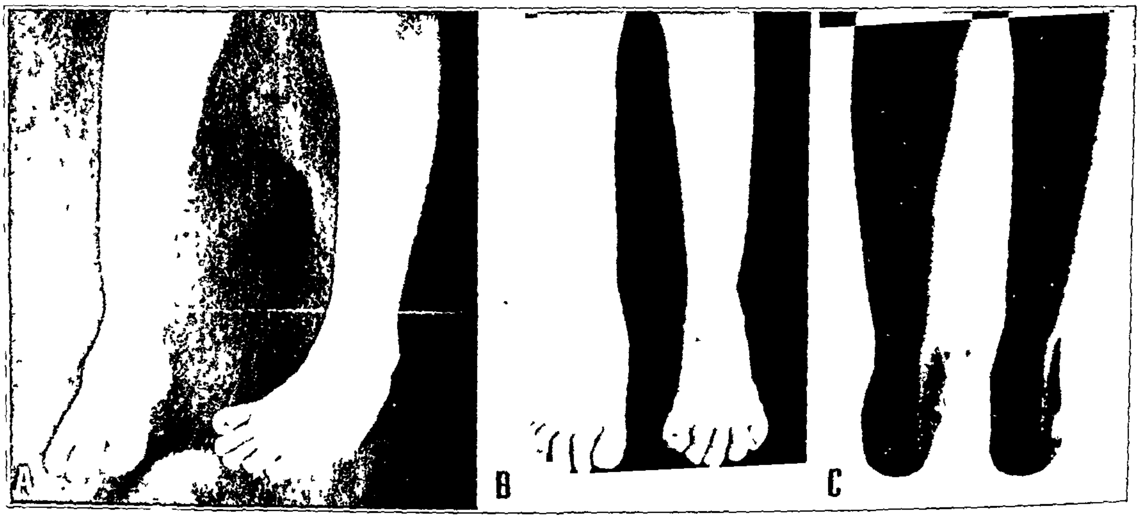

Fig. 2

R. W., aged seven. Recurrence of the deformity in all its components. *B* and *C* are photographs taken three years after operation, showing excellent results. About 10 degrees of residual equinus.

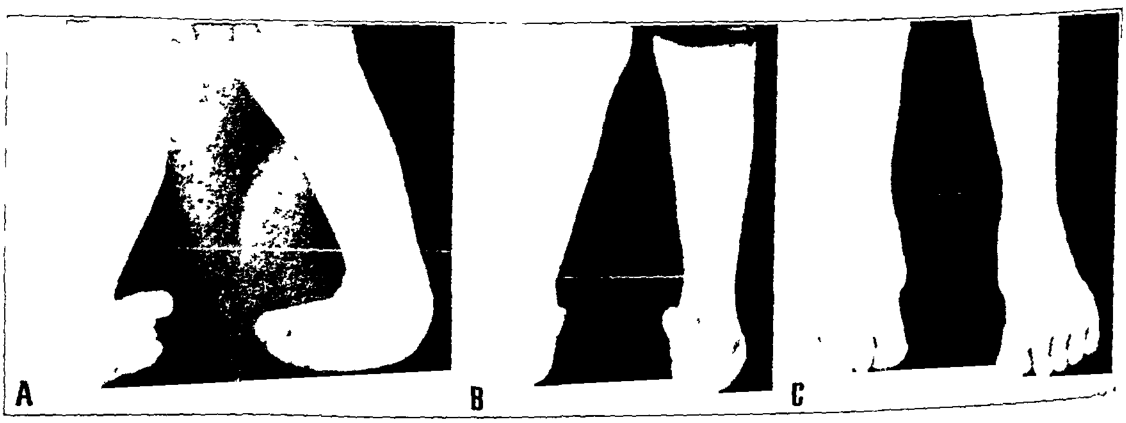

Fig. 3

J. W., aged two. Rigid recurrence of all components; deformity was never completely corrected. *B* and *C* are photographs taken one year after operation, showing a fair degree of correction. No further surgery was performed.

nail or made it more cumbersome. Use of such a wire merely complicated the operative procedure, and in the authors' hands it did not prove helpful. Reinforcement of the juncture of the nail with the plate was secured by thickening of the plate at this point. The casting of nails with three angles (130 degrees, 140 degrees, and 150 degrees) allowed for close coaptation of the plate to the femoral shaft, regardless of the angle of the neck at the time of reduction and without the necessity of bending the apparatus (Fig. 2). The casting of a nail of each angle in a normal and in a short length obviated overdrive in severely comminuted fractures. The removal of the streamlined head and its replacement by a ledge behind the head of the nail, for application of a hook extractor, facilitated removal when threads in the base of the nail were stripped and a threaded puller could no longer be used.

Such a nail can be used successfully in even the severely displaced and comminuted type of paratrochanteric or intertrochanteric fracture (Fig. 3-A). It has the added advantage of being of great practical use in the difficult subtrochanteric type of fracture, high in the femoral shaft (Fig. 3-B), and in that rare type in which both the neck and the trochanteric region are involved (Figs. 3-C and 3-D). It is possible by open reduction to fit the fractured fragments into satisfactory alignment, and to hold them there by internal fixation. Frequently even the lesser trochanter can be engaged, and the fragments can be held in reduction by the upper screw. If nailing is done properly, with the nail well placed in the head of the femur, coxa vara will not develop unless the nail breaks, bends, or pulls out of the bone. The nail most frequently used has an angle of 130 degrees and is three inches in length; it is made of non-electrolytic material. The authors have not used the blade-plates described by Blount and Moore, although these undoubtedly are effective.

Fig. 4-A

Gradual telescoping of fracture site, without the development of coxa vara, allows protrusion of the nail into the head during healing. This is called "overdrive", although the nail may not have been driven through the head at operation. Such telescoping at the fracture site generally ceased by the end of three months, with the development of union.

to the tendon sheath were noted several times. Fusion of the anterior tibial tendon with the extensor hallucis longus was noted once.

CONCLUSIONS

1. Recurrence of the deformity in club-foot is not infrequent.
2. The faulty mechanism of the muscles everting and inverting the foot may be the cause.
3. Recurrence of the deformity may be prevented by transposition of the anterior tibial tendon in selected cases.
4. This operation is not recommended for correction of the deformity.
5. The transposed anterior tibial tendon may be restored to the original insertion when planovalgus or overcorrection is apparent.
6. Satisfactory results were obtained in ninety-one, or 83 per cent., of the 110 feet so treated.

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DISCUSSION

DR. J. HIRAM KITE, ATLANTA, GEORGIA: The discussion of this paper can be divided into two sections, tendon transplantation and club feet.

First, when should we transplant tendons? In times past, our only indication for transplanting tendons was a gross muscle imbalance, as in poliomyelitis or some injury to the nerve which has completely paralyzed one group of muscles.

There is no gross muscle imbalance in congenital club-foot; it is only an apparent imbalance. In the original untreated club foot, the anterior tibial and posterior tibial tendons are seen to contract, because the fore part of the foot is adducted and the heel is inverted. The tibial muscles are in a shortened position, and the line of pull is such that they work at an advantage. When the club-foot deformity is corrected by any means, the muscles resume a normal balance. When the club-foot deformity recurs, there is again only an apparent imbalance, due to the shortened muscles and line of pull. When the foot has been restored to a normal position, the muscles will be in normal balance.

Dr. Garceau and Dr. Manning say, "If . . . supination occurs on dorsiflexion (extension) of the foot, we believe transposition of the anterior tibial tendon is indicated". Personally, I would not feel justified in operating with so slight an indication.

Second, Dr. Garceau and Dr. Manning have had a very resistant group of recurrent club feet to treat, because of the stiffness and rigidity following the early treatment. They say that 113 operations had been done on 110 feet before the average age of six and one-half years, and that the feet were still not corrected. They say, "Forceful wrenchings had previously been done on many feet. In each instance, the deformity recurred two or more times".

How long will it take us to learn to stop treating club feet by "forceful wrenchings" and by the use of the eight different cutting operations which were used on this group? I am almost persuaded that there is still a need to continue the teaching of conservatism in the treatment of club feet.

The authors say, "This operation was chosen, rather than arthrodesis, transtarsal wedge osteotomy, or other bone-cutting operations".

They say that in addition to anterior tibial transplantation, most patients had wedged casts for two or three months postoperatively, and that these two procedures gave very satisfactory results in 83 per cent. of the series. I wonder why they are so reluctant to give the less spectacular eight to twelve weeks of casts and wedgings some credit for their good results.

Twenty-seven of these 110 feet needed some additional operations after the tendon transplantation, and they have still a long growth period ahead of them.

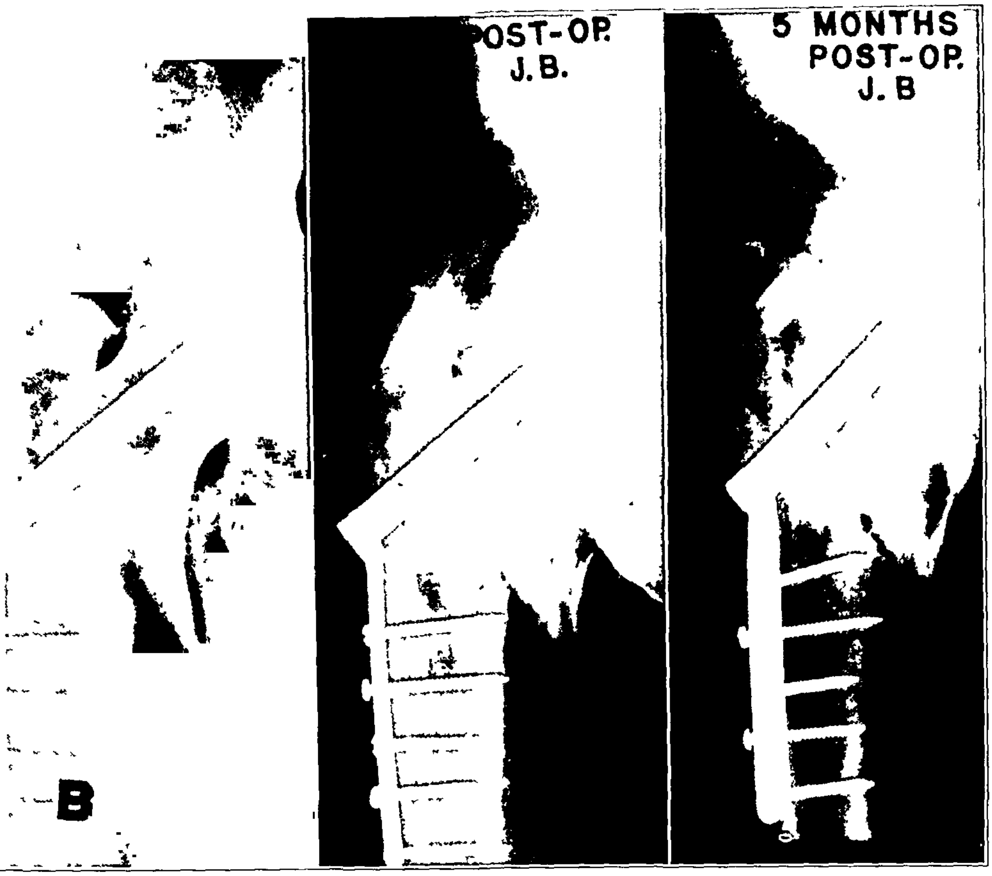

FIG. 4-B

In certain instances, protrusion progressed after three months. No protrusion has been noted in this series after the seventh month, which indicates that solid union does not always occur in these fractures before the seventh month.

ANAESTHESIA

The authors believe that the low immediate mortality rate is due in large measure to the choice of anaesthesia and to the use of a blood transfusion at operation. Preoperative morphine sulphate and hyoscine are given an hour before a minimum dose of avertin. Complete anaesthesia is induced twenty minutes later with a mixture of cyclopropane, nitrous oxide, and oxygen.

OPERATIVE AND ROENTGENOGRAPHIC TECHNIQUE

Both a surgical team and a roentgenographic team who are acquainted with the nailing procedure must be employed for the smooth and rapid handling of such cases. Trochanteric fractures should be handled with gentleness and a minimum of manipulation. Simple trochanteric fractures sometimes become comminuted on the operating table by vigorous manipulation. Light traction, moderately forceful internal rotation, slight hip flexion, and gentle abduction secure the best reduction. The uninvolved hip may be abducted fully to fix the pelvis and to allow for lateral roentgenograms, as necessary. The foot of the table may be dropped to facilitate this manoeuvre. Following standard sterilization and draping, a lateral incision, through all structures to the upper third of the femur, should be made with minimum laceration of muscle tissue. This is of great importance, as will be seen from the two cases in this series in which gas gangrene developed. A skin clip may be placed over the location of the femoral head, as a guide in driving the nail and as a marker for subsequent roentgenograms. After films have been taken to show the reduction, a Jewett nail with the proper angle and of the proper length may be chosen.

The point of entrance of the nail below the trochanteric ridge will depend upon the

FIG 1-E

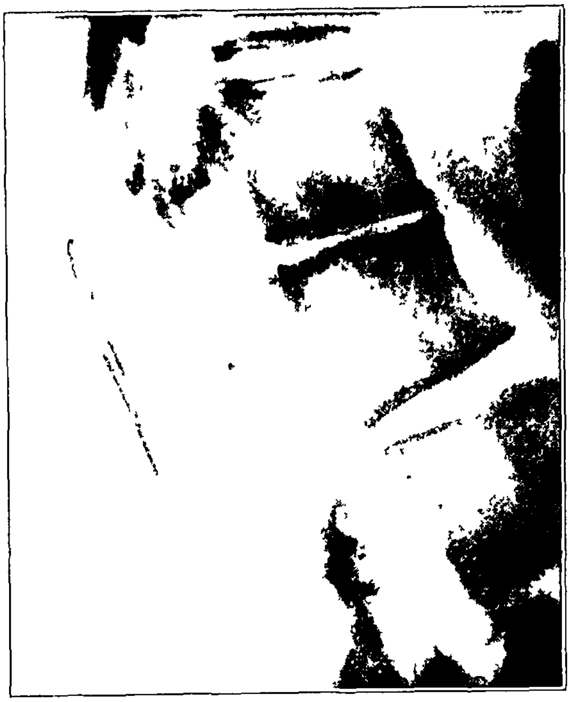

FIG 1-F

Present condition, six years later, shows slight redisplacement, but sound bony fusion laterally; the wire has broken.

individual mention. The patients have been treated by several surgeons in the Department, which will account for the variations in the method used.

METHOD OF REDUCTION

Closed reduction was attempted by the author in three patients with complete paraplegia, at a time when it was felt that the outlook in these cases was almost hopeless, and that it was unfair to increase the burden of the patient and of the nursing staff by open operation. The following method was employed:

The patient was laid prone on the operating table, with a pillow under his lower chest, which was placed over the rest employed to hyperextend the spine in abdominal operations. Local infiltration anaesthesia was used. With a moderate degree of traction on the arms and legs, the spine was flexed by the elevation of the rest; at the same time, pressure was exerted over the spine, below the dislocation. Reduction was accompanied in each case by the usual satisfactory sensation which one associates with the reduction of any dislocation, and the spinous processes were felt to assume their normal relationships.

One must admit, on theoretical grounds at least, that *open* reduction of the interlocking articular facets, under the careful control of one's eye, is the method of choice. It is a relatively simple procedure, which should be done under local infiltration anaesthesia. The muscles can always be stripped off the damaged vertebrae with the greatest of ease, having been separated by the trauma and subsequent hemorrhage. The operation should be preceded by very careful roentgenography to ascertain the exact extent of the damage, particularly that to the posterior structures. The interlocking articular processes are readily identified, the cartilage of the lower facets gleaming white when the wound is swabbed. If the dislocation is in the lower thoracic region, the processes tend to be perched upon one another, tip to tip. Little forward displacement occurs at this site, because the spinous process of the upper vertebra is very oblique, and, if unfractured, will not permit displacement. It is not unusual to find the articular facets already unlocked and commencing to mate, requiring only extension of the spine to complete the process. In the lumbar region, however, true interlocking occurs. It has been recommended

that partial removal of the upper facets of the lower vertebra be performed, on one or both sides, to facilitate reduction without undue manipulation or roughness. The writer only rarely found this necessary. Gentle flexion of the spine to unlock the facets, with backward traction on the spinous process of the upper vertebra, has been enough to secure unlocking; and accurate reposition is then effected by hyperextension. On one occasion the spinous processes of the two affected vertebrae were wired together to prevent redisplacement. This was in a patient with no paraplegia. The wire has not affected the functional recovery, which is complete. The man served in the Army overseas throughout the War, and was classified as A.1 on entry, within eight months of his accident (Figs. 1-A to 1-F, inclusive).

On both the open and closed operations, reduction is maintained by the application of a plaster cast. It there is no fracture of the posterior structures, a complete jacket is applied. If there is any doubt about the integrity of the posterior column, a plaster boat is felt to be safer, following reduction.

SITE OF LESION

Has the degree of cord injury any relationship to the site of the lesion, or to the degree of trauma to the spine? It will be seen from Table I that the junction of the fixed and movable parts—that is, the thoracolumbar region—is the most important site of injury. Of the major group of thirty-six cases in which the fracture-dislocation occurred near the thoracolumbar junction, twenty-five patients had complete paraplegia; three had partial paraplegia; and eight had no paraplegia. Of the small group of five cases in which the lesion occurred at or below the level of the second and third lumbar vertebrae, however, two with very gross displacement were complicated by complete paraplegia; one, with interlocking, by partial paraplegia; and two patients, one of whom showed the grossest displacement between the fourth and fifth lumbar vertebrae, had no paraplegia (Fig. 2).

FIG. 2

Case 2, L. S. This is a case of fracture-dislocation between the fourth and fifth lumbar vertebrae, with gross displacement. There was no paraplegia.

This relatively low incidence of nerve damage in the group whose lower spine was involved must be due to (a) the large size of the neural canal and (b) the greater strength of the cauda equina as compared with the spinal medulla. Gross displacement at the thoracolumbar junction, however, must indicate severe cord injury, although the converse—that is, slight displacement with simple interlocking—is no indication whatever of the degree of cord damage.

The case labeled "None, becoming complete" (Table II) is of especial importance. This case was diagnosed upon admission to

nail chosen, and is usually nearer the ridge than in intracapsular fractures (an average of three-quarters of an inch). The femur should be drilled at this point, with a hole sufficiently large to prevent shattering of the cortex when the nail is driven in. In most cases, the trochanter must be lifted forward, as the nail is driven horizontally inward and upward. Fixation of the plate with two screws will then allow trial rotation of the hip. If grating occurs, faulty position of the nail or overdrive is present. In this event, roentgenograms are taken, and the position or length of the nail is corrected, as necessary. If rotation is free in extension and flexion, the remaining screws are placed; roentgenograms are taken; and the wound is closed during their development. Should changes in the nail position be necessary, a few seconds only are required for re-exposure. Much time will usually have been saved.

With many of these hips to nail, the authors have been concerned over the amount of roentgen rays to which the doctors, residents, and nurses are exposed while check-up films are being taken. After experimentation with various types of cones and lead-lined tunnels, two simple methods of protection have been employed. A small lead diaphragm, devised by the Roentgenographic Department, is placed in the tube aperture. The small central hole of the lead diaphragm is fashioned so as to prevent the spread of rays beyond the area of an eight by ten film. When the anteroposterior view is taken, the patient is lying on a tunnel, which allows rapid change of the cassette without moving the patient. There is no danger of the hands of the personnel being exposed to roentgen rays during this episode. Frequently, when the lateral film is taken, however, someone must hold the cassette, so that it is pushed strongly into the side of the patient, just below the ribs and above the crest of the ilium. Wound retractors can be used as hooks over the edge of the sterile-draped cassette, superiorly and laterally. It is held firmly in place against the patient, and the hand is screened by the cassette. The lead lining, in the back of every cassette, prevents the rays from going through. By actual Victoreen test, the hand behind the cassette receives no measurable roentgen rays. For such a view, the roentgen tube is placed at the inner side of the knee of the normal lower extremity, which has been abducted. Usually a lateral postoperative view can be taken with the hip in flexion, which avoids the difficulty of holding the film. With a trained surgical and roentgenographic team, the average operating time may be held to thirty minutes or less.

POSTOPERATIVE CARE

After operation, the patients are placed in light traction to prevent external rotation. This temporary traction during the early postoperative period provides a considerable amount of comfort. It is usually ten days before a toe-to-groin Thomas brace with pelvic band and knee lock can be delivered. Such a brace is used until union is solid, to prevent external rotation. Some of the patients have been allowed up in a chair within a few days after the operation. However, early weight-bearing, even with the brace, is harmful. It may cause the nail to break, bend, or even protrude through the femoral head. In the postoperative roentgenograms, it has been noticed that the nail protrudes farther into the proximal head fragment, chiefly during the first three months, before union has occurred (Fig. 4-A). In some few cases, further protrusion has been noted after the third month (Fig. 4-B). No protrusion has been noted after the seventh month. It is probable that too active weight-bearing can encourage this protrusion. In the majority of the patients, some absorption of bone at the fracture site took place, with gradual approach of the nail tip towards the articular margin. Early movement of the patient, without actual weight-bearing, is beneficial. The authors do not feel the need for early complete mobilization of these patients, advocated by others. Postoperative pneumonia is not so greatly feared since the advent of penicillin. Pulmonary embolus is still feared, although only two cases have been noted in this series.

Close observation and general care pay high dividends in results in these aged people.

INTRAMEDULLARY ONLAY GRAFTS FOR DEFECTS RESULTING FROM SHATTERING FRACTURES *

BY LIEUTENANT COLONEL FRANK G. MURPHY

Medical Corps, Army of the United States

Intramedullary bone grafts have been used on occasions since bone-grafting operations first were performed. Current surgical treatises do not recommend their use, nor are they generally advocated by orthopaedic surgeons. Watson-Jones stated that intramedullary grafting is far less satisfactory than inlay or onlay grafting, and Armstrong has written that "the introduction of a hard cortical plug into the medullary cavity seriously diminishes the blood supply to the bone-ends, and often produces non-union." Boyd reported several cases in which he used an intramedullary fibular graft in cancellous bone with success. Küntscher, in 1940, and more recently Soeur, described the intramedullary fixation of fractures with metal rods. They stated that the normal physiological osteogenesis was not disturbed materially.

Because of the extensive destruction which occurs in long bones as a result of the high-velocity projectiles used in modern warfare, unusual surgical complications have been encountered. A considerable number of these bone injuries included gap defects; these were complete in some, while in others partial bridging by a thin strip of bone, connecting the main fragments, resulted. Metal fragments remained in many patients after early healing.

In a considerable number of cases, massive onlay grafts were not applicable or even feasible, because of comminution and loss of much cortical-bone substance. Here it was found possible to force a graft along the medullary canal, well into the cancellous bone of the end, where it was held fast. The protruding portion of the graft could then be approximated to the shaft of the other fragment, where it could be fastened securely with screws. In the first few cases this procedure was carried out more as an expedient than by design. It was not very difficult to perform, and it fulfilled the requirements for the proper implantation and application of a bone graft.

The indications for combined intramedullary and onlay grafts are (1) ununited fractures near the joints; (2) gap defects in the shafts of the long bones; (3) non-union in which the resultant atrophic cortices are of insufficient hardness to anchor retaining screws; and (4) partial gaps which are bridged by a thin fragment of cortex.

The immediate objectives which are planned are as follows: (1) bridging of the fracture defect; (2) maximum coaptation of the graft to the fragments; (3) moderate stability without the use of additional foreign material; and (4) the avoidance of the hazard of fracture of the graft by placement of screws distant from the fracture site.

PRELIMINARY TREATMENT

All infected tissue, sequestra, accessible metal, and other foreign material are removed. All manifestations of infection should have subsided, and the sinuses should have remained closed, for a period of at least six weeks prior to operation. Long months of delay are no longer necessary before a definitive surgical procedure is begun. Split-thickness skin grafts may be used to hurry the closure of a large clean wound. After the wounds have healed, soft-tissue defects are properly repaired by appropriate plastic procedures.

OPERATIVE TECHNIQUE

The exposure should be thorough, preferably by incisions through healthy tissue rather than through scar tissue. The fracture fragments should be exposed adequately,

* Originally prepared for the monthly Staff Meeting of Battey General Hospital, Rome, Georgia, December 4, 1945. Presented before the Chicago Orthopaedic Society, April 12, 1946.

Feeding the patients is a difficult problem, and in itself requires special nursing care. A high-protein intake should be insisted upon. Fluids are supplied by infusion, if necessary, during convalescence. Vitamin-B therapy is almost routine. Close attention is paid to the skin at the point of traction, and the back is inspected daily. Incontinence is treated immediately by indwelling catheters; frequent changes of bed linen are essential. Prompt cessation of sedation is demanded. The importance of cardiac investigation, consultation, and medication, when necessary, should always be borne in mind. We should remain continuously aware of the fact that these patients are old, afflicted with many debilitating factors aside from their fractures, and have been injured badly.

COMPLICATIONS

1. Infections

Four cases of infection occurred in the patients who had been operated upon. In two patients, an infected hematoma developed. One of these was evacuated spontaneously, and healed promptly. The other was still draining, but without general reaction, when the patient died of inanition on the thirty-fifth day after operation. Gas gangrene, resulting in death, developed in two men. Autopsies were performed on both. Both had two or more lines of incision through the deep muscle tissues lateral to the upper third of the femur, which destroyed the blood supply to a sizable portion of muscle tissue. One of these patients was 103 years of age. It is the authors' feeling that, in these aged patients, with vitality of muscle tissue at a minimum, further destruction of the blood supply by an incision (especially if accompanied by laceration of the deep tissues) may promote much

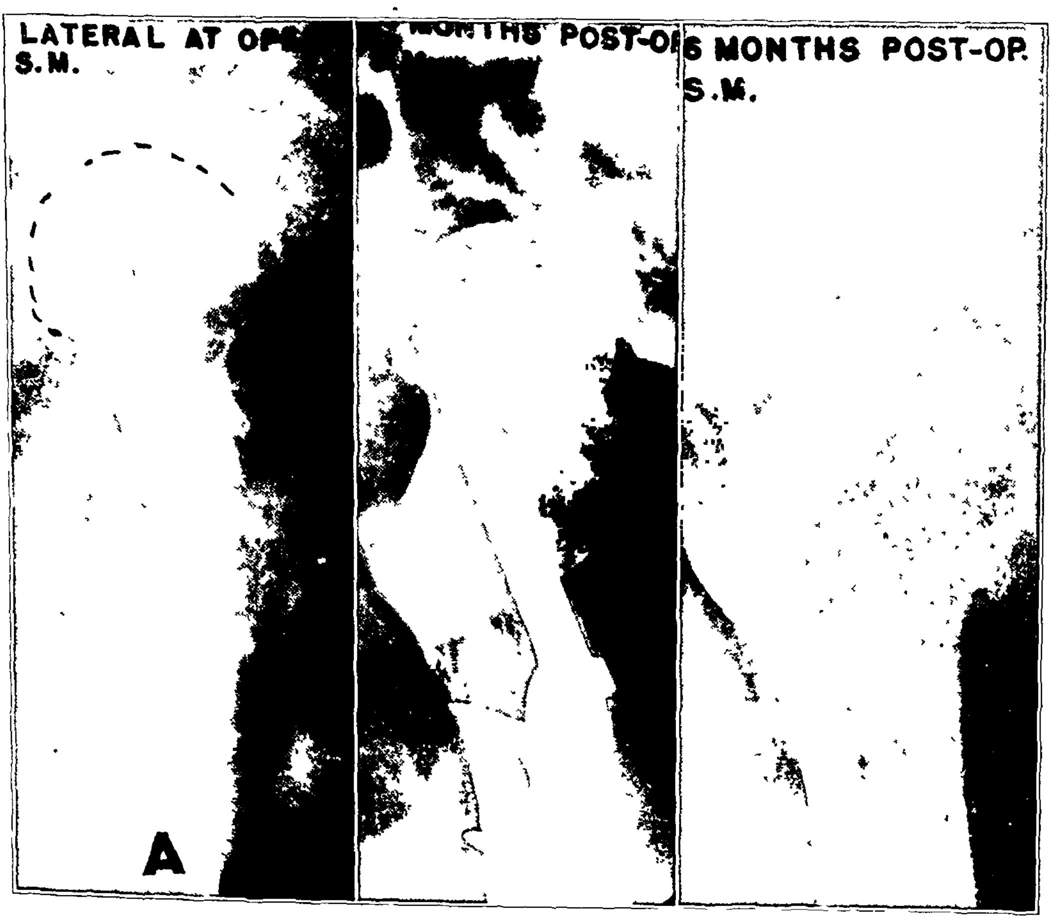

Fig. 5-A

Protrusion of overdrive gradually developed after operation. Removal of the nail following union relieved symptoms routinely.

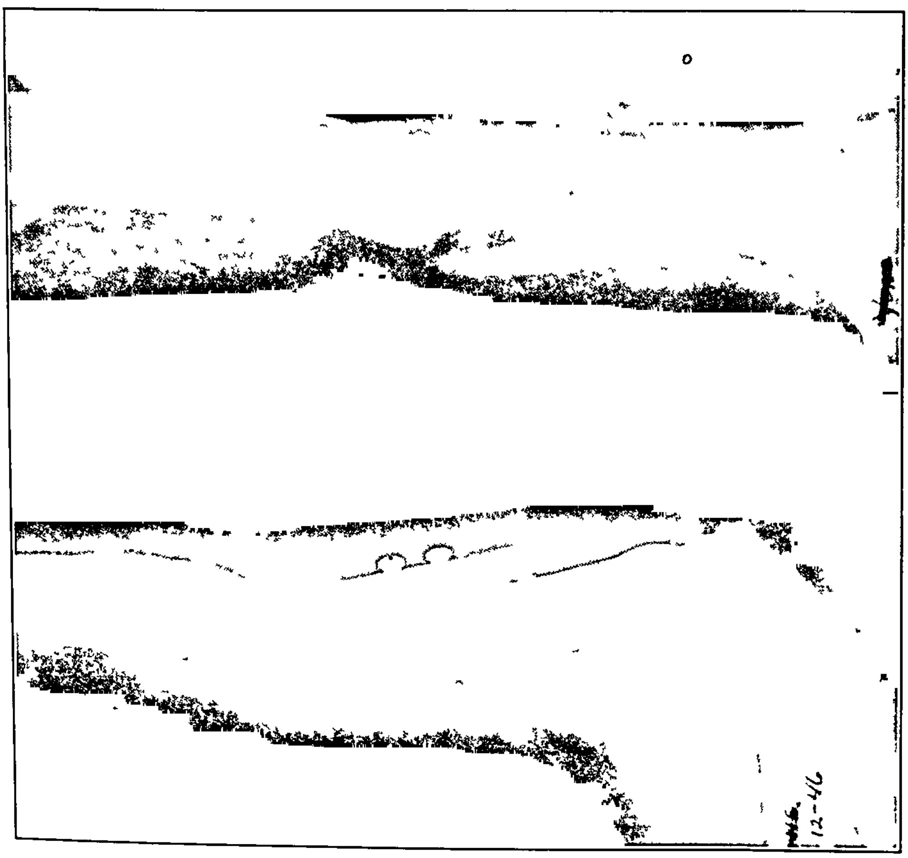

FIG. 1

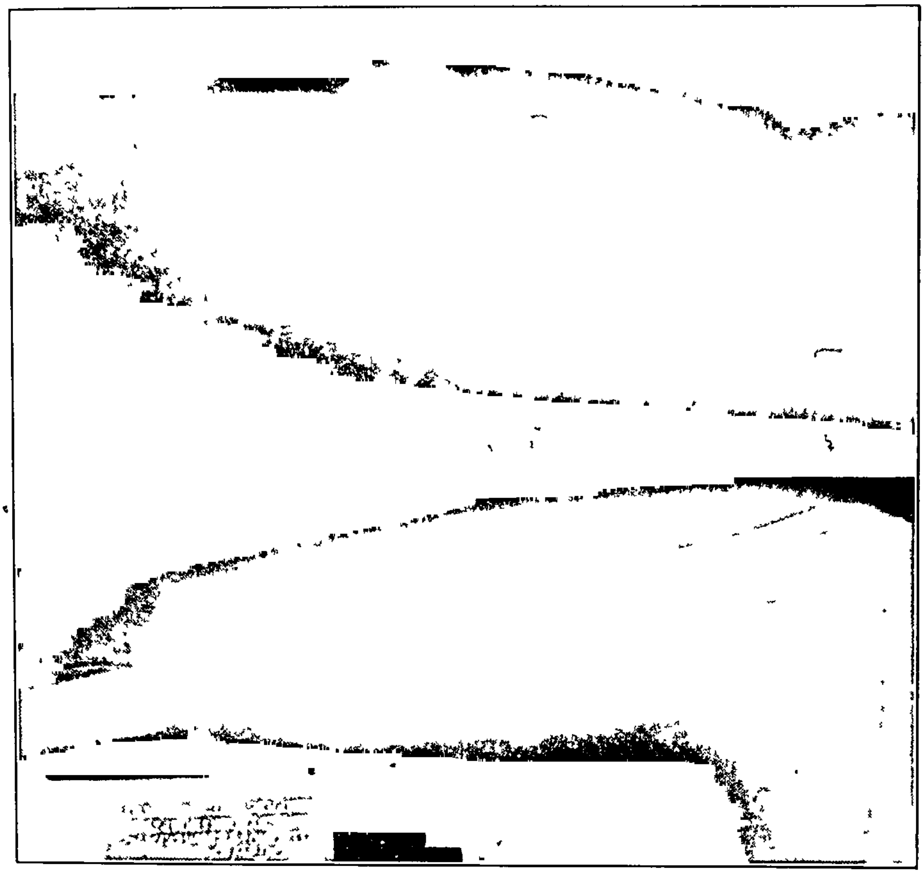

FIG. 2

FIG. 1: This patient was injured January 19, 1945; operation was performed on the humerus August 21, 1945. Roentgenograms, taken March 12, 1946, show fracture of the graft. Another graft will be required.

FIG. 2: Injury was received December 4, 1944; humerus was operated upon June 4, 1945. Fracture of the graft occurred on September 30, 1945. Roentgenograms, taken March 12, 1946, show union of fracture of graft. At present, strength is fairly good.

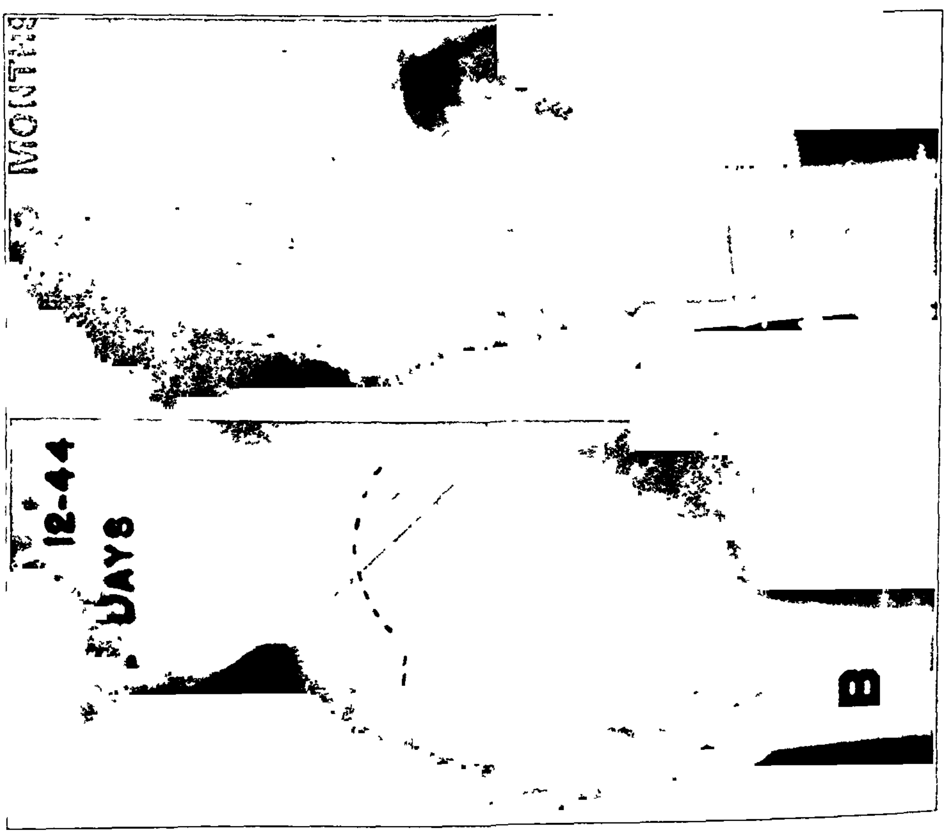

Fig. 5-B

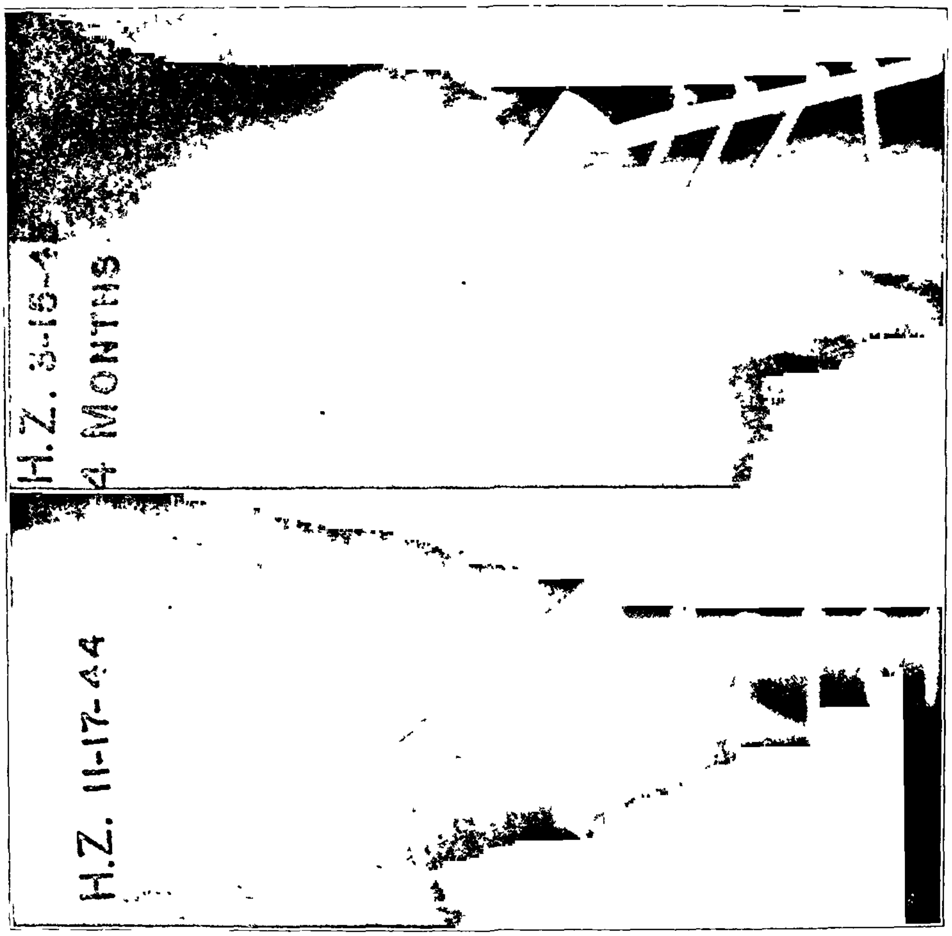

Fig. 5-C

Fig. 5-B: Disruption of nail through the side of an atrophic head and neck occurred on the second day after operation. This nail was withdrawn and a new one was inserted; the roentgenogram at the right shows the appearance of the head three months later.

Fig. 5-C: Early weight-bearing, against advice, caused these screws to pull out of the shaft of the femur four months after operation. This required subsequent surgery.

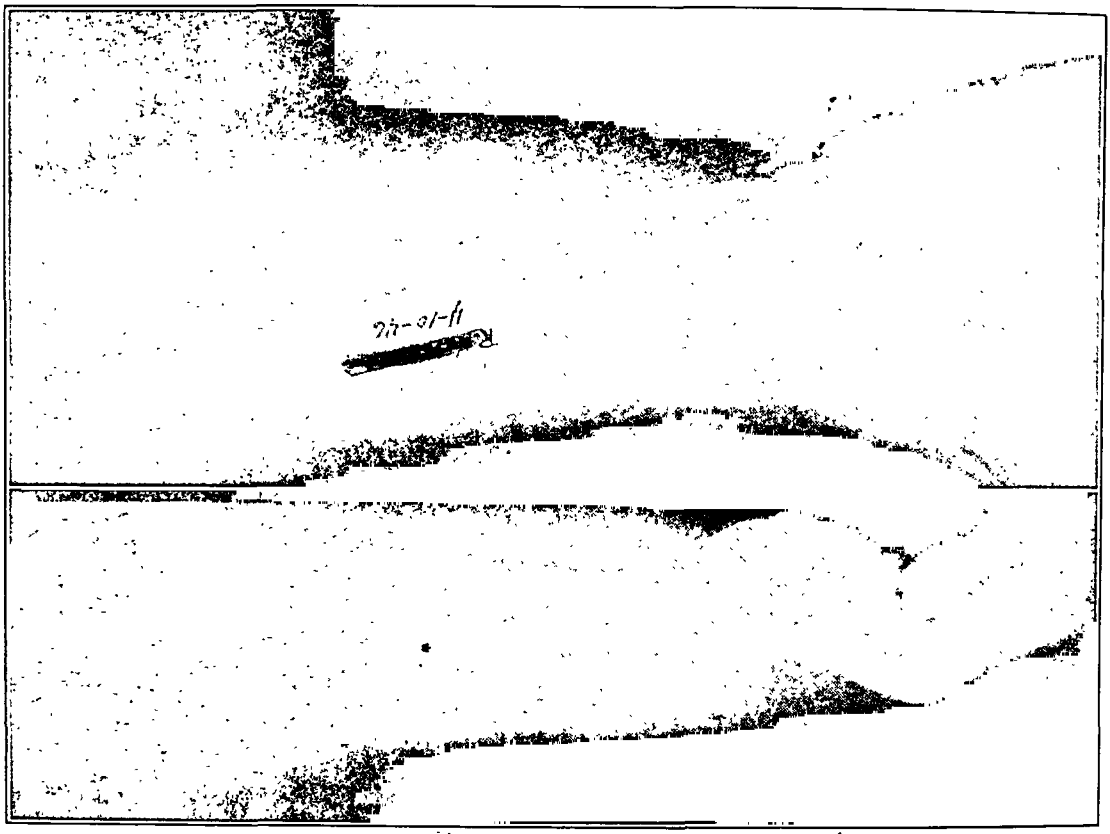

FIG. 3

Patient was injured March 8, 1945; operation on humerus was performed November 10, 1945. Roentgenograms, taken on April 10, 1946, show angulation. Function is good.

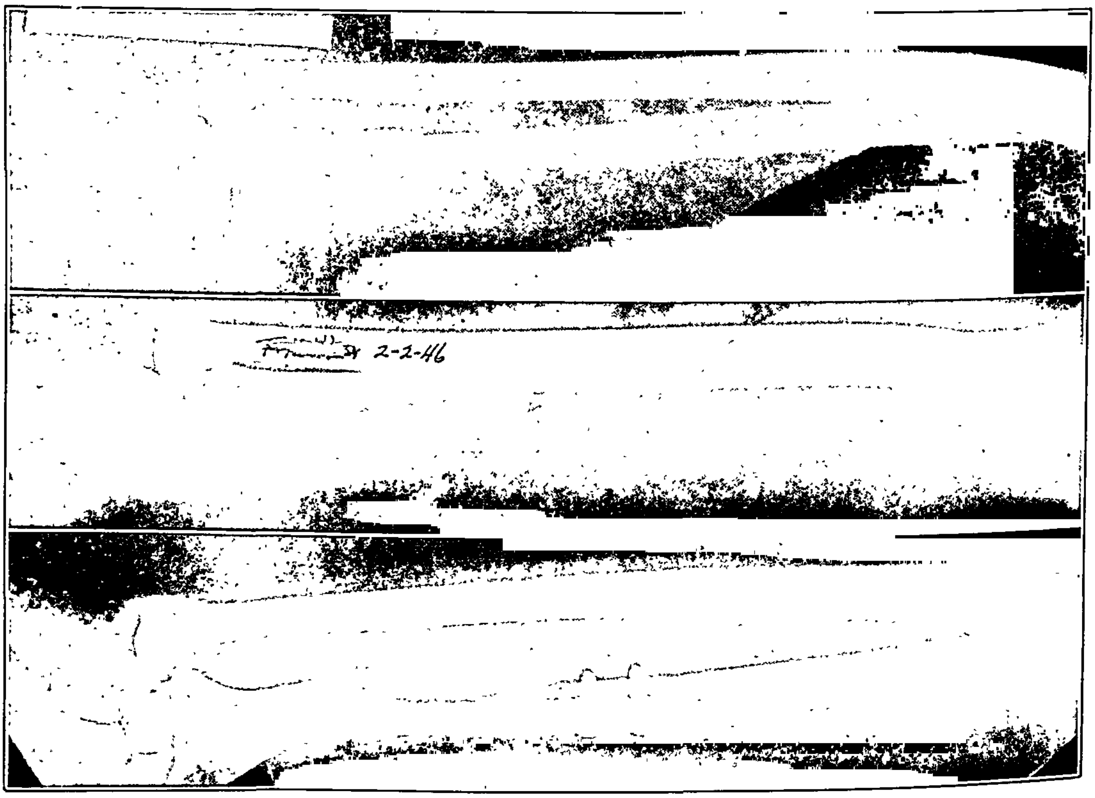

FIG. 4

This patient, injured March 17, 1945, was operated upon August 24, 1945. These roentgenograms of the radius were taken on February 2, 1946. Strength and function are good.

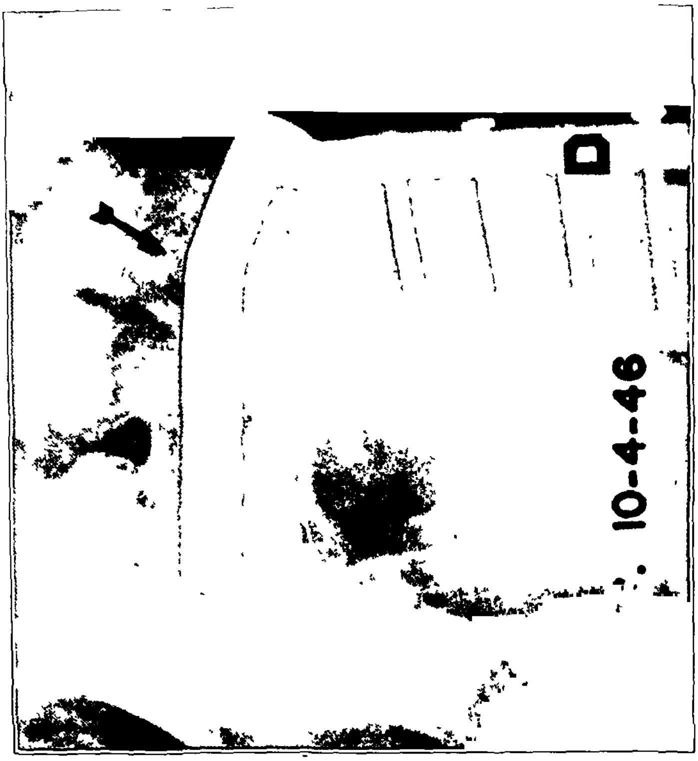

Fig. 5-E

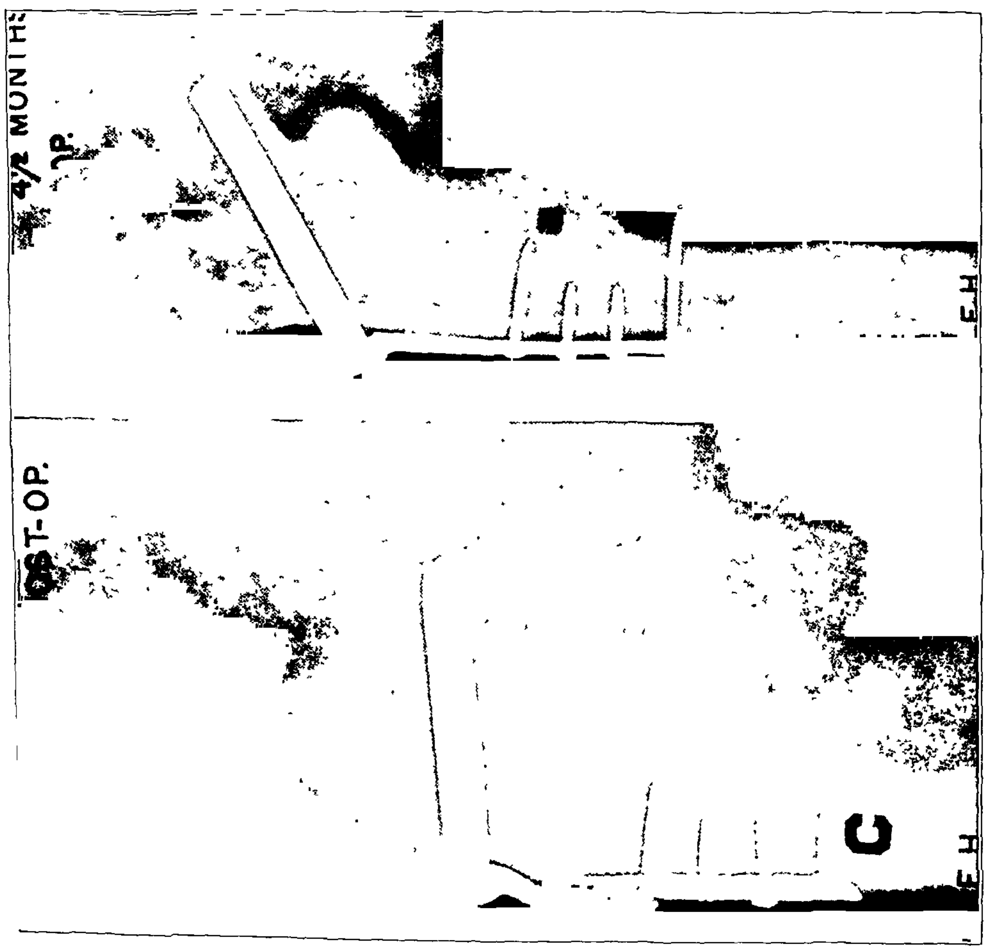

Fig. 5-D

Fig. 5-D: Fracture of the nail, either in the plate or in the three-flanged portion. This occurred twice in the flange and once in the nail. Two nails were replaced and one was removed. In all three patients, union was satisfactory.

Fig. 5-E: Bending of the nail occurred once. Removal of nail, with application of traction, resulted in union, although with mild coxa vara.

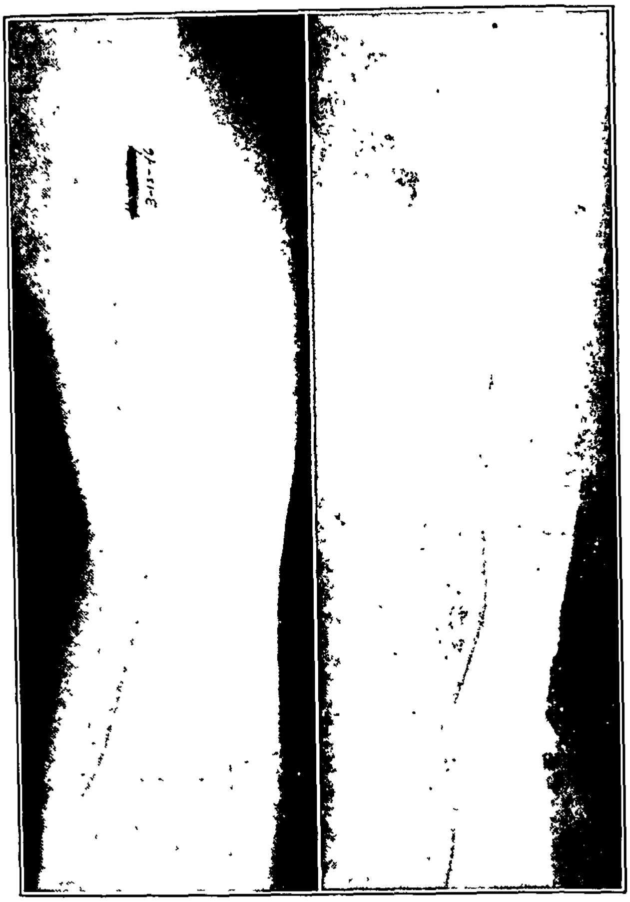

Fig. 5

Fig. 6

Fig. 5: Patient was injured December 23, 1944; operation on femur was performed November 2, 1945. These roentgenograms were taken March 15, 1946. The patient is walking with a caliper brace.

Fig. 6: Injury was received July 2, 1944; the femur was operated upon July 24, 1945. Anteroposterior roentgenogram was taken on February 27, 1946. The patient is walking with a caliper brace.

TABLE I

Cases in Which Operation Was Performed

Location of Injury	No. of Cases	Location of Injury	No. of Cases
Femur	8	Clavicle	3
Tibia	5	Humerus	8
Fibula	3	Radius	9
Metacarpal	5	Ulna	11

subperiosteally, above and below the defect. Interposed scar tissue should be removed completely with a sharp periosteum elevator or a gouge; it can best be removed *en masse.* The sclerosed ends of the fragments are perforated into the medullary cavity, and the end which is to receive the bone graft is opened well and enlarged, if necessary. The main fragments are aligned, and a careful examination is made to determine the most suitable site of application, and the size and shape of the proposed graft. Obstructing bone projections are excised, and other necessary trimming is carried out. A suitable graft is removed from the tibia. A long graft which extends 7.5 centimeters beyond the fracture site is advisable, because it gives better early stability and can be fastened with screws, well away from the fracture site. The graft is fashioned at one end so as to fit snugly into the intramedullary space previously prepared in one fragment; and it is then rotated, so

more necrosis than would occur in patients in a younger age group. As was found in severe battle wounds (to which these wounds are comparable), such conditions are extremely favorable to the development of gas-producing anaerobes.

2. Pulmonary Embolus

One would expect a considerable incidence of pulmonary embolus in such a series after operation, but only two instances of this condition were found. Both of these patients died; on one patient, an autopsy was performed. The embolus causing this fatality arose from the deep veins of the uninjured leg, there being no sign of thrombosis of the veins on the injured side. The patient's treatment had been entirely neglected for ten days prior to her entry to the Hospital. Apparently thrombosis had occurred, unsuspected by us. Manipulation, incident to operative reduction, cannot be disregarded as a factor in the fatal termination of this case. We believe that the fatal embolism in the second case on the thirteenth postoperative day is not an operative mortality. There was no clear-cut instance of embolism among the patients who died, following treatment by traction.

3. Pneumonia

Postoperative pneumonia occurred in two patients (2.1 per cent.), and was treated successfully without fatality.

4. Overdrive

The most common complication in this series has been that resulting from driving the nail too close to the dome of the femoral head (Fig. 4-A). The nail need not have been driven through the head at the time of operation to have made this complication possible. The authors had not realized that there would be much absorption at the fracture site in the healing of these fractures. These patients left the Hospital at a much earlier date than those treated by traction, and at the time of their discharge check-up roentgenograms showed a well-driven nail, close to the cortex of the femoral head, which we judged to be an excellent supporting structure. It was only when the patients were called back for follow-up that it was discovered in their roentgenograms that bone had been absorbed at the site of fracture, with telescoping. This caused the nail to protrude into the acetabulum, since its base was affixed firmly to the shaft of the femur through the attached plate (Fig. 4-B). Strangely enough, not many of the patients had complained of a grating sensation on movement of the joint, nor had they complained of much pain. The roentgenogram disclosed this situation, rather than the statement of the patient. In certain other patients, several attempts were necessary at operation to place the nail satisfactorily in the femoral neck. In a few of these, after several attempts, the operation had to be terminated before the nail had been placed satisfactorily, because of the poor condition of the patient. Although the position of the nail was not perfect, it was felt that it did not extend beyond the cortex of the femoral head, and that healing would be uneventful. During subsequent months, these nails continued to protrude through the head into the acetabulum. Their removal has been simple and without operative complication. Traumatic arthritis, where such nails have cut notches in the acetabular roof, has not caused these patients severely annoying symptoms. Overdrive is most apt to occur in the severely comminuted intertrochanteric fracture and the trochanteric fracture which is more nearly through the base of the neck. It has been noted, however, that, although the fracture line often becomes absorbed and the neck telescopes down on the nail, the angle of the head and neck fragments relative to the shaft remains the same, and does not bend into a coxa vara position. In all, nine nails have been removed for various reasons. In four situations, removal of the nail-plate was considered to be justified (Figs. 5-A, 5-B, 5-C, 5-D, and 5-E). The first situation, and one which occurred most frequently, has been protrusion of the nail; second, disruption of the nail from its contact with the head or the shaft of the femur;

that its flat surface rests with maximum coaptation on the cortex of the other fragment. In some cases it may be necessary to prepare a partial groove for the onlay portion, as in the classical inlay procedure. The graft is tapped firmly and snugly into the intramedullary space of one fragment; its flat surface is clamped to the other fragment, where it is fixed firmly with stainless-steel screws. These screws are placed quite far distant from the fracture site, and are passed through both cortices of the underlying fragment. If the intramedullary portion of the graft is placed in loose cancellous bone—as, for instance, in the proximal end of the humerus—a transfixion screw may be necessary to prevent movement. Finally, bone chips from the upper end of the tibia or from the ilium are packed around the graft and into the defect, so as to fill vacant spaces. Early stability is accomplished, so that the danger of displacement during closure and the application of the cast is obviated. Soft tissues are closed in the usual manner, care being taken in the placement of sutures not to produce undue tension. A snug-fitting, well-molded cast is applied.

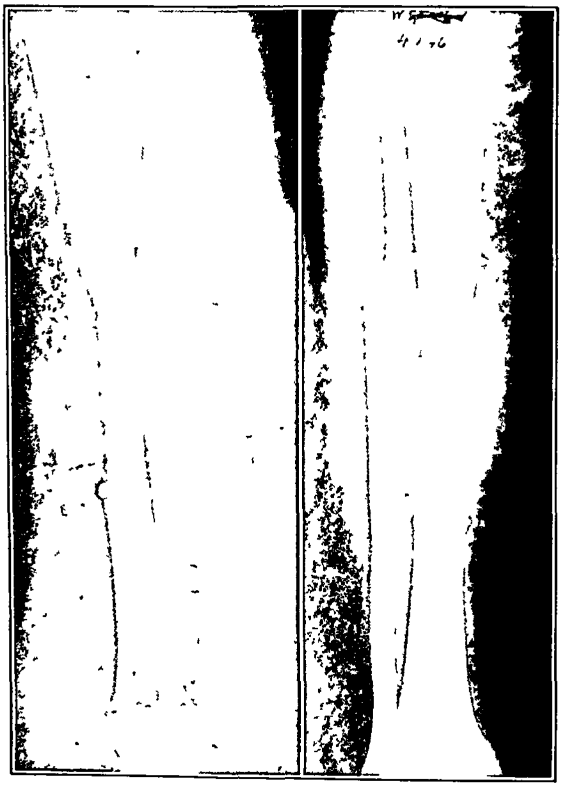

Fig. 7

Fig. 8

Fig. 7: This patient, injured January 7, 1945, was operated upon July 30, 1945. Roentgenograms were taken April 1, 1946 The patient is walking with a brace.

Fig. 8: Injury was received November 11, 1944; patient was operated upon June 1, 1945. Roentgenograms of the leg were taken March 23, 1946. The function is excellent.

POSTOPERATIVE CARE

After operation, the principal problem is prevention of swelling, and it is of paramount importance to elevate the extremity. Immobilization is continued in a snug plaster cast for several months. A change of cast is essential whenever there is loosening, which occurs as a result of muscle atrophy.

An estimate of the period of maximum weakness of the graft is between three and six months after its insertion. A study of the roentgenograms suggests that the convalescent period necessary for the bone graft to become strong enough to safely assume function is much longer than was estimated heretofore. This period varies greatly in different individuals, and also according to the location of the fracture and the placement of the graft.

The method has the following advantages:

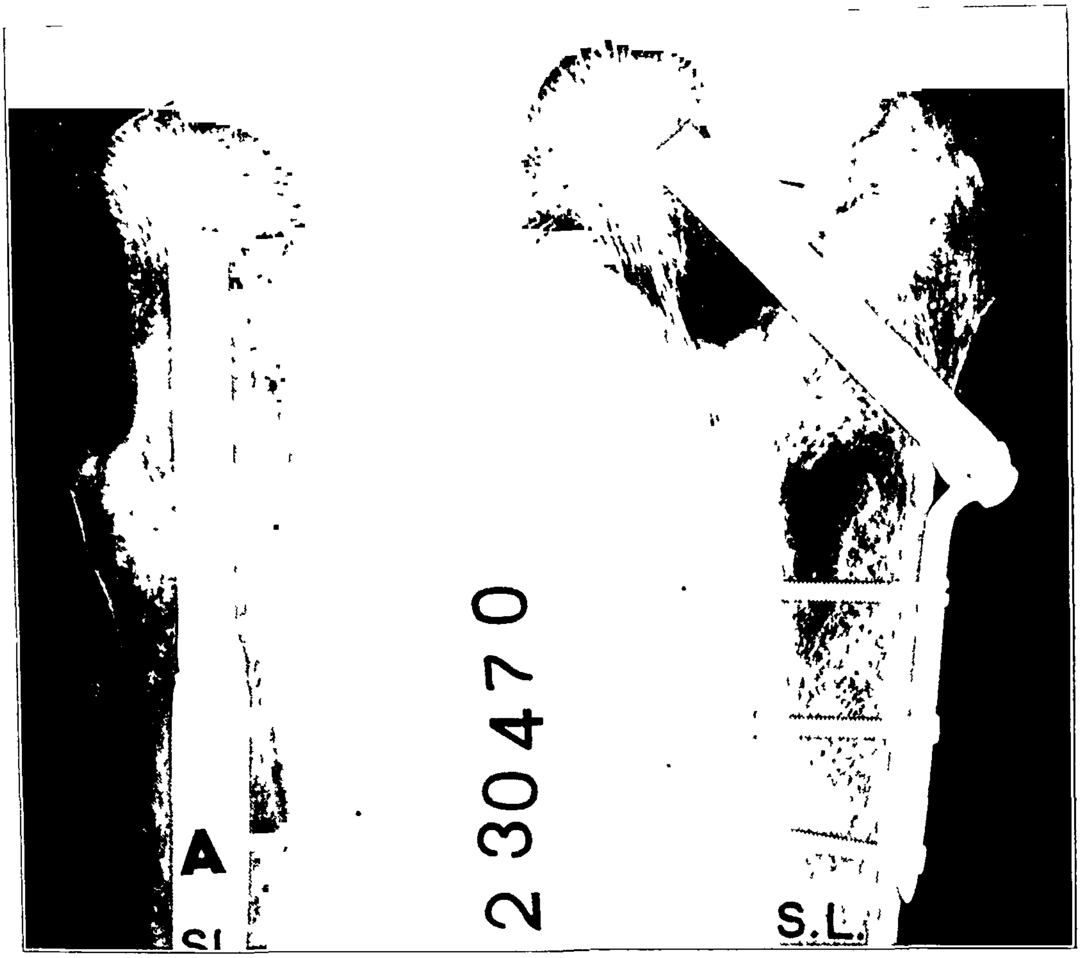

Fig. 6-A

Roentgenogram of autopsy specimen, with nail in place, shows internal structure of bone. Most favorable site for the point of the nail to be imbedded is the lower portion of the neck and head. Nail shown was placed too high in the neck, but despite this, it had held and union was progressing.

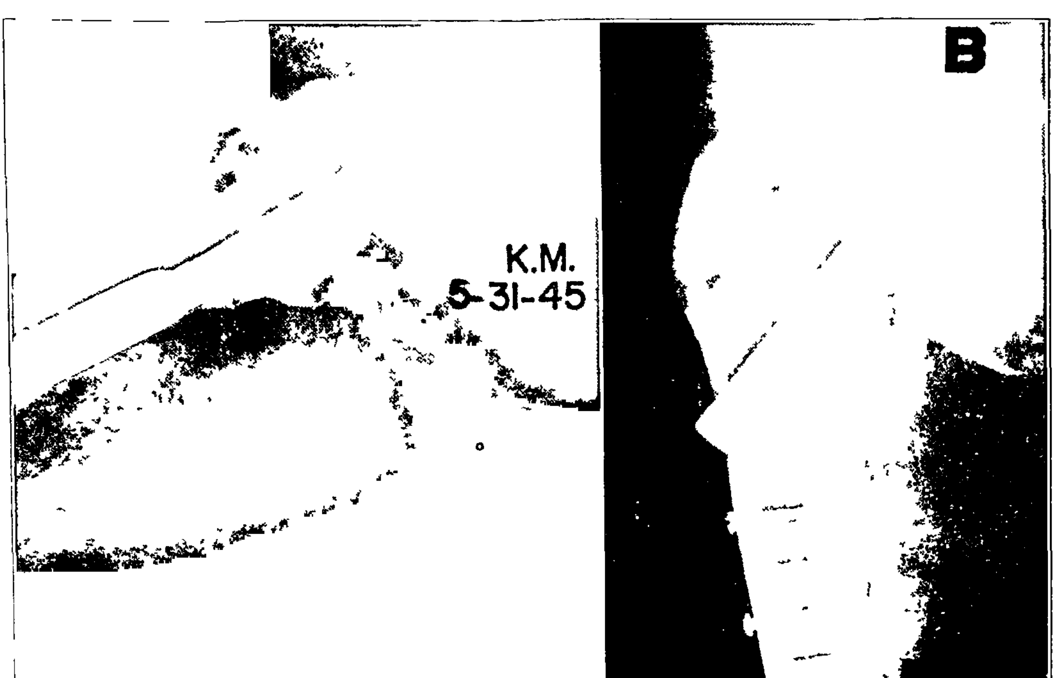

Fig. 6-B

Example of perfect nailing, with nail placed low in head and centered in lateral view. Fracture of lesser trochanter was disregarded; no clinical objective or subjective symptoms present related to it.

1. Maximum coaptation of the graft to the fragment is achieved readily.
2. A minimum of foreign material is necessary.
3. The graft is applicable in locations in which massive onlay grafts would be cumbersome and not feasible.
4. There is no sequestration of the graft.

The operation was performed in a series of fifty-two cases at Battey General Hospital (Table I). Early complications were encountered in ten cases:

1. In three cases, fracture of the graft occurred, because of too early removal of the immobilization.
2. Rarefaction around the screws was encountered in two cases. This was thought to be due to electrolytic action, since metal fragments were present in the soft tissues.
3. In one case, the graft projected into the joint at operation, when it was inadvertently driven through the lower end of the radius. Later this portion (one centimeter) was removed. No joint injury resulted.
4. A sinus formed through a scar in two cases, with postoperative infection. The infection was mild and did not interfere materially with the bone and callus formation.
5. Angulation in cancellous bone was present in one case.
6. Fracture of the donor site in the tibia occurred in one case.

LATE REPORTS ON THE CASES OF INTRAMEDULLARY ONLAY GRAFTS

Follow-up reports with roentgenograms were obtained on forty-two of the fifty-two patients. The sources of information were orthopaedic surgeons at Army General Hospitals and Veterans Hospitals, orthopaedic surgeons who were treating discharged veterans, roentgenographic laboratories, and individual patients. A résumé of the findings is as follows:

Reports were received on all three cases of grafting of the clavicle. Good healing occurred in all.

Of the eight humerus cases, good healing took place in four. One bone healed with angulation, but with good function. Three were unsuccessful because of (1) absorption of the graft; (2) failure of "take"; and (3) fracture followed by absorption of the graft. In one case, which previously had been reported as unsuccessful because of fracture of the graft, the graft finally united after a long period of immobilization.

Reports were received on seven of the nine radius cases. In five, the grafts had been successful; two were failures. Of the two failures, one bone was ununited after five months, and absorption of the graft after five months was reported in the other.

Of the eleven ulna cases, reports were received on seven. Six grafts were successful; one had non-union eight months after operation.

Of the five cases of metacarpal grafting, healing took place in four. One graft was fractured by too early manipulation of the finger, followed by absorption of the graft.

Reports were received on six of the eight femur cases. Four grafts were successful; two

FIG. 9

This patient was injured in the hand January 27, 1945, and was operated upon June 18, 1945. Roentgenogram, taken March 15, 1946, shows absorption of graft, applied to the metacarpal.

third, the necessity for replacement of a bent or broken nail; and fourth, continuous discomfort over the plate distal to the trochanteric region. Nail protrusion occurred chiefly among the earlier patients, before the authors were aware of the possibility of this situation. It has rarely happened in the later cases, since the proper length and angle of the nail have been insisted upon.

5. Nail Breakage, Bending, or Disruption

In three instances, the nail became fractured from early weight-bearing (Fig. 5-D). In two of these, the broken nail was immediately replaced by a new one, with ultimate firm union. The third instance occurred when a patient walked without support the second day after operation. Wide separation of the fragments resulted. Traction was employed, and union, although delayed, eventually took place with marked external rotation of the lower extremity. In one instance the nail bent through the three-flanged portion. This nail was extracted, and the patient was put in traction; satisfactory union resulted, but with some coxa vara. In four other instances the nail tore out of the bone in which it had been inserted (Fig. 5-B). In two of these, the nail ripped out of the side of a decalcified femoral neck and head. In one a new nail was placed, but protrusion gradually took place as union occurred, and the nail will have to be removed. In the other instance, a severely deformed arthritic old lady, union occurred without pain but with considerable deformity. This patient had not been ambulatory before operation; and, since she is without pain, no attempt has been made to remove the nail-plate. In two instances the screws pulled out of the femoral shaft (Fig. 5-C). In the first, the nail was replaced, and the patient obtained an excellent result. The second patient had the nail removed, and a subtrochanteric femoral osteotomy was performed to correct the external-rotation deformity which occurred; good weight-bearing and ambulation were obtained, although with marked restriction of hip motion.

Roentgenograms of autopsy specimens from patients whose fractures had been reduced and repaired by nail fixation, confirmed by anatomical studies, show that the nail should be implanted in the inferior portion of the femoral head and neck, and that there it will be imbedded in the densest portion of the calcar femorale (Fig. 6-A). The anteroposterior roentgenogram should show the nail implanted in the lower portion of the head, and in the lateral view it should be centered (Fig. 6-B). It should not approach closer than one centimeter to the articular surface of the head, for fear of gradual protrusion. Screws fastening the plate to the femoral shaft should perforate and grasp both the proximal and the distal cortices. Where convenient, the lesser trochanter may be engaged by one of the screws, although failure to so secure it does not vitiate a good functional result (Fig. 3-A).

6. Subtrochanteric Fracture

Production of a subtrochanteric fracture at operation, during an attempt to nail an intertrochanteric fracture, has occurred on five occasions (Figs. 5-B and 5-C). It has not been a very annoying complication, since the nail supports both fractures satisfactorily. No untoward results have been seen from this operative accident.

7. Non-Union and Aseptic Necrosis

No instance of non-union of a trochanteric fracture has occurred among the survivors. There have been two cases of delayed union. The first occurred in a patient whose screws pulled out of the femoral shaft. The second patient walked on the eighth day after operation, against advice, and bent the nail so that the neck became angulated 40 degrees into a coxa vara position. No case of generalized aseptic necrosis of the femoral head has occurred from the use of these nails. A few localized areas of necrosis near the nail tips have occurred in patients when the nail was lying high in the head of the femur, and these have been associated with traumatic arthritic changes.

TABLE II

UNSUCCESSFUL RESULTS FOLLOWING OPERATION

Complication	Location	No. of Cases
Fracture of graft	Femur	1
Fracture and absorption	Humerus and metacarpal	2
Absorption	Humerus and radius	2
Non-union of graft	Humerus, radius, and ulna	3
Delayed union	Femur	1

were unsuccessful. One patient suffered a fracture of the graft six months after operation, and one was still in traction eight months after operation.

Of the five tibia cases, reports were received on three. Two grafts healed well; one had moderate union eleven months after operation.

Good healing occurred in all of the three fibula cases.

A follow-up study of these forty-two cases leads to the following observations:

1. The graft undergoes a process of atrophy during its early period,—namely, for three to five months after its insertion. Evidence supporting this belief is (a) increased radiolucency, as seen in the roentgenograms; (b) the accidental fracture of the graft in several cases, after considerable time had elapsed; and (c) a feeling of weakness in the grafted area for several months. The atrophic process resulted in increased fragility and secondary fractures, noted in several patients, and in absorption of a portion or the whole of the graft in others.

2. The graft does not possess osteogenic power when implanted, but it may take on this property later, or after a process of reconstitution takes place. Evidence to support this belief is the union of the fractured graft following a long period of immobilization.

3. Proliferation of the bone, as observed from late roentgenograms, seems to arise from the adjacent fragments. The bone-forming process apparently extends along the graft at some time after the graft undergoes so-called reconstitution. Later the graft itself increases in size.

4. In no case was there evidence to support the belief that the intramedullary portion of the graft causes atrophy or deterioration of the fragment into which it has been implanted.

SUMMARY

Of the fifty-two patients operated upon, follow-up studies were obtained in forty-two. Satisfactory results were reported in thirty-three cases. The unsatisfactory results observed in the remaining nine cases are recorded in Table II.

NOTE: The author wishes to acknowledge with deep appreciation the assistance and cooperation of Captain Leo Markin, M. C., and Captain Robert Hampton, M. C., Assistant Chiefs of the Orthopaedic Service at Battey General Hospital.

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8. Mortality (during the Hospital Stay)

Of thirty-eight patients treated conservatively, mainly with traction, thirteen died during their hospital stay,—a mortality of 34 per cent. On the other hand, among ninety-five patients treated with internal fixation, there were only twelve deaths, a mortality rate of 12.6 per cent. The hospital mortality rate following conservative treatment, in our hands, was much larger than that resulting from surgical fixation. By a mortality rate of 12.6 per cent. in the nailed group is meant that these twelve patients died before leaving the hospital. We feel that the operation was responsible for but four of these deaths. Two elderly women died the day after operation,—one of shock (traumatic and operative) and one of pulmonary embolism. Two men died of gas gangrene as a result of operation. The eight remaining deaths (seven due to cardiac failure and one to embolus) took place from the fifth to the twenty-eighth day after operation. We feel certain that these deaths are not the result of operative trauma, since an analysis of the patients treated in traction shows that 70 per cent. of the hospital mortalities occurred before the twenty-sixth day.

9. Senile Psychoses

The development of severe and permanent senile psychosis is considered an extremely serious complication. Not only are these patients divorced from the rest of their active lives, but they demand continuous and expensive care, and continue an existence of considerable debasement and suffering. Of the thirty-eight patients treated conservatively, four (11 per cent.) were transferred to mental institutions, because of the development or aggravation of senile psychoses and dementia. Of the ninety-five patients operated upon, only two (2.1 per cent.) were transferred to mental institutions. This decrease in the incidence of severe psychoses among the group operated upon is due in part to an earlier return to active status, and in part to extensive intramuscular vitamin therapy.

10. Decubitus Ulcers

In only eight patients of the series having operations (8.4 per cent.) did pressure sores of any nature develop.

11. Disabling Deformities of the Hip and Knee

There were no knee deformities incident to the nailing procedure. The final range of motion of the hip was improved over that obtained in patients treated with traction.

12. Incontinence

Although the occurrence of incontinence was as common among the patients in traction as in those treated with fixation, the latter were immeasurably easier to handle.

SURVIVAL RATE

Due to the advanced age of the patients who sustain intertrochanteric fracture, it is evident that not many patients will survive for more than a few years, regardless of trauma or operation. A review of the cases treated by traction shows that only 32 per cent. were living one year from the date of fracture. By the end of the second year, 29 per cent. were alive; at the end of four years, only 13 per cent. were alive. In comparing the group treated by traction with those treated by internal fixation, we note a decided contrast. In the group treated by internal fixation, 72 per cent. were living one year from the date of the fracture, 38 per cent. survived two years, and even 30 per cent. of those in whom nailing was carried out four years ago have survived.

LENGTH OF HOSPITAL STAY AND EXPENSE

The average patient with an intertrochanteric fracture is an unwelcome guest in the hospital ward for a prolonged stay. In those cases treated in traction, the average number

WEDGE OSTEOTOMY OF THE SPINE WITH BILATERAL INTERVERTEBRAL FORAMINOTOMY

Correction of Flexion Deformity in Five Cases of Ankylosing Arthritis of the Spine

BY HENRY BRIGGS, M.D., SIDNEY KEATS, M.D., AND PHILIP T. SCHLESINGER, M.D., ORANGE, NEW JERSEY

From the New Jersey Orthopaedic Hospital, Orange

The treatment of flexion deformity of the spine, associated with ankylosing spondylitis, presents a difficult problem. Very frequently, flexion deformity of the spine develops, despite vigorous systemic antirheumatic therapy and adequate bracing of the back. Such a patient often presents an arcuate kyphosis in the thoracolumbar region, with loss of the normal lumbar lordotic curve. The patient stands with hips and knees in flexion; the whole trunk, as well as the head and neck, is thrust forward. The thorax is flat and appears immobile; respiration is frequently almost exclusively abdominal. As this chronic, painful condition progresses, loss of weight, anaemia, and the typical pinched, drawn facies appear.

The significant pathological feature is the involvement of the intervertebral articulations with the ensuing ankylosis of the spine. A gradual ossification of the interspinal ligaments, the anterior and posterior longitudinal ligaments, the ligamenta flava, and the capsular ligaments of the apophyseal joints follows, to a varying degree. The ossification of the anterior longitudinal ligament is characteristically seen early in the Marie-Strümpell type of ankylosing spondylitis. This ankylosis eventually limits the deformity, but also precludes satisfactory correction of the deformity by conservative measures.

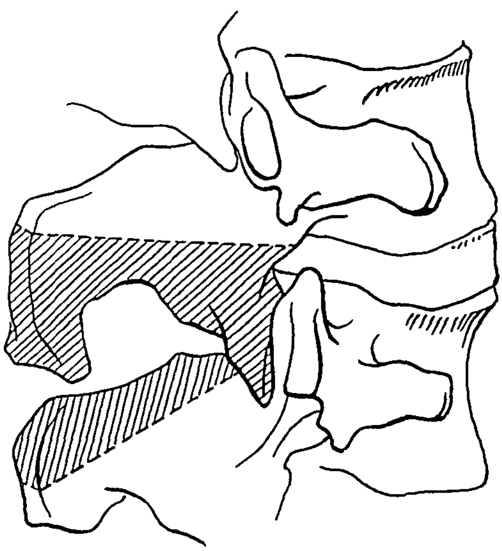

Fig. 1

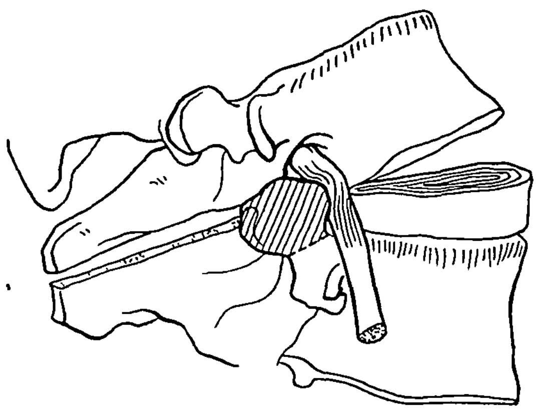

Fig. 2

Fig. 1: The wedge-shaped pattern of the posterior elements resected in osteotomy of the spine includes a portion of the spinous processes, laminae, articular processes, and pedicles of the contiguous vertebrae.

Fig. 2: Illustrating the mechanism of compression of the roots in the intervertebral foramina by the superior articular process of the inferior vertebra, when hyperextension is effected beyond the normal range. The shaded segment indicates the amount of the process and pedicle removed in completing the foraminotomy.

Since the original description of osteotomy of the spine for the correction of flexion deformity in rheumatoid arthritis by Smith-Petersen, Larson, and Aufranc, the authors have developed a different operative technique in a series of five patients operated upon at the New Jersey Orthopaedic Hospital. It is our purpose to present a preliminary report of these cases.

of hospital days was ninety-eight, or fourteen weeks. The patients treated by internal fixation remained in the hospital an average of fifty-seven days, or a little over eight weeks. Even the eight weeks' stay of the patients who were operated upon was a kindness rather than a necessity. This method of treatment almost halves the length of time the patient needs to remain in the hospital. Many patients are able to pay but a small part of their hospital expense. The major share of the cost of treatment must be borne by hospital endowment or by other community resources. This reduces the availability of such resources for other needy cases. Were expense alone to be considered, this might not prove important; but, when viewed in the light of other foregoing statistics, it certainly becomes so.

SELECTION OF CASES

In the past two years the authors have refused to operate upon two patients. One of them lived eight days, and the other twelve days, in traction. The responsibility for not operating upon these elderly patients is serious. These two clearly had sufficient vitality to have withstood the operative procedure. Perhaps had we nailed their fractures, they might have lived. Often we felt that the operation was merely the means of keeping the patient comfortable during the terminal stage, only to find that the patient lived after internal fixation. This is much the same experience as that found in the early days of nailing a fracture of the neck of the femur. The authors have been surprised by the number of patients who have benefited by surgical fixation, even when past experience had indicated that they would die in traction. We now operate upon and nail all intertrochanteric fractures.

SUMMARY

1. Internal fixation reduced the hospital mortality to 12.6 per cent., as compared to 34 per cent. after treatment in traction.
2. Severe senile mental deterioration occurred in 2.1 per cent. of the cases following internal fixation, as compared with an incidence of 11 per cent. in the group treated by traction.
3. The survival rate at the end of four years among the patients operated upon was 17 per cent. higher than in the group upon which operation had not been performed.
4. All complications were reduced sharply in those patients submitted to internal fixation.
5. Although union of the fracture took place in all survivors, the functional result in those treated by internal fixation was vastly improved.

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DISCUSSION

Dr. Rex L. Diveley, Kansas City, Missouri: I am very happy to comment briefly on this excellent study. This is the type of fracture in which it makes very little difference what type of treatment you are accustomed to using; all of these fractures usually heal, but infrequently the results obtained are very poor. A year and a half ago Dr. Cleveland told us that he was carrying on this study, and we informed him that we would carry on a similar study at Kansas City General Hospital. The only difference in our study has been that we are using a Moore blade-plate, and feel that we get less fragmentation with a plate than with a three-flanged nail.

Over a three-year period we have studied 120 consecutive cases, and we have had a mortality in that series of 32.2 per cent. as compared with 36 per cent. in the authors' series. The youngest patient was twenty-seven years of age and the oldest was ninety-four, with an average of seventy-two years. Fifty-six were fe-

The new technique consists of a wedge resection of the posterior elements of the spine (Fig. 1). This wedge includes a portion of the spinous processes, laminae, articular processes, and pedicles of the adjacent vertebrae. This procedure is, in actuality, a wide bilateral foraminotomy, as previously described by Briggs and Krause. The advantage of this operation is that a satisfactory correction of the deformity may be obtained at one operation and at one level.

The mechanism of the operation may be clearly demonstrated on the cadaver. Such a study shows that the amount of correction depends entirely upon the size of the wedge removed. As correction is obtained, the fulcrum, or pivot of angulation, is along the posterior margin of the intervertebral disc, usually at the superior border. As more than a normal hyperextension is gained, the superior articular process of the vertebra below compresses the roots in the intervertebral foramina at this level against the disc and vertebral body. The removal of the superior articular process of the vertebra below, with some of its pedicle, frees the nerve roots from impingement and allows for a degree of correction beyond normal hyperextension (Fig. 2).

We wish to present the operative procedure employed. The lower lumbar region is selected for the site of osteotomy, which, we believe, should be performed where the anterior longitudinal ligament is well calcified. It is helpful to make a roentgenogram preoperatively, with a marker placed on the patient to identify a lumbar vertebra.

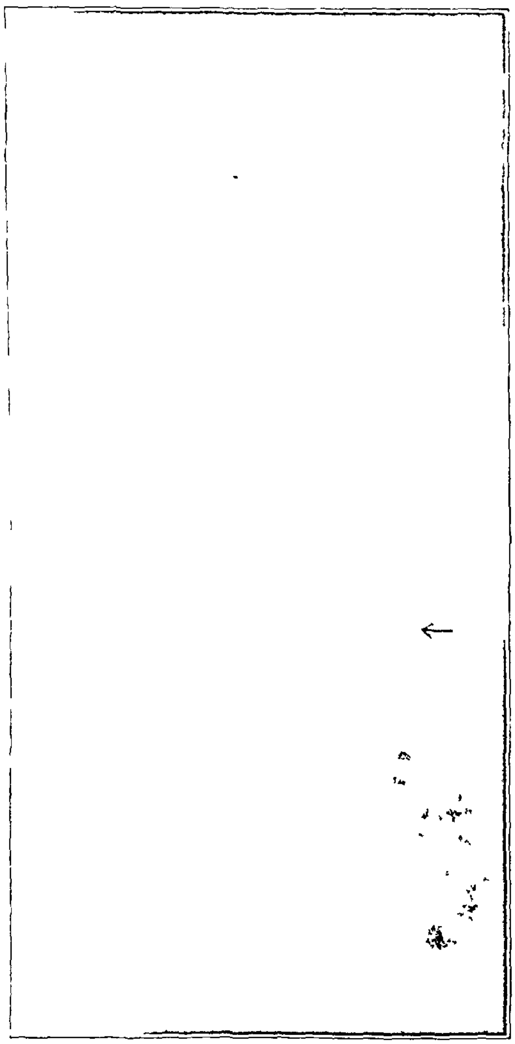

Fig. 3-A

Case 1, K. D. B. Preoperative roentgenogram.

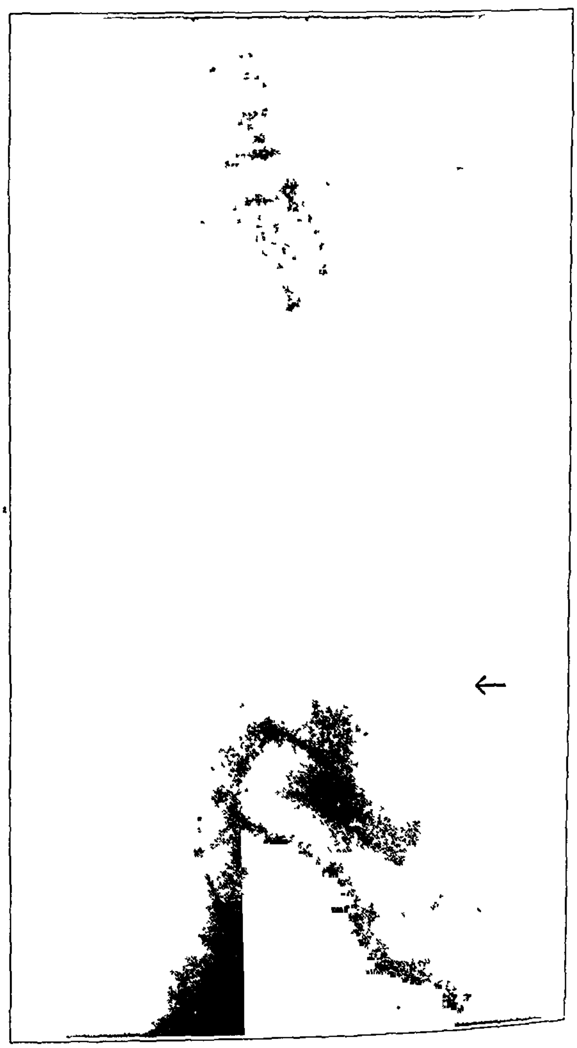

Fig. 3-B

Postoperative roentgenogram.

males and sixty-four were males. One group was treated conservatively and another was treated by open reduction, for comparison. The conservative treatment consisted of traction, well-leg traction, splints, and, in the largest series, abduction casts. In the series treated conservatively, we obtained good results in 34 per cent., satisfactory results in 43 per cent., and poor results in 23 per cent. In the series treated by open reduction (we have been able to follow only nineteen for a sufficient length of time to know the results), we have obtained 63 per cent. good results and 32 per cent. satisfactory results; there were only 4 per cent. that we termed poor. These results would seem to be far better than those obtained by the conservative method of treatment. Therefore, we highly endorse this method of treatment of intertrochanteric fractures.

Dr. Paul L. Norton, Boston, Massachusetts: The authors are to be congratulated for their forthright and comprehensive analysis of this series of 133 cases of intertrochanteric fractures with complications. This report is both timely and encouraging. In the past, the intertrochanteric fracture has had a high nuisance value, because it was felt that the fracture would heal regardless of the method of treatment and, therefore, it was primarily a nursing problem.

Analyses of end results have demonstrated that we are dealing with a very serious injury, both as regards the fracture and, more particularly, the life of the patient. This is a fracture of the aged. Of our series of 258 cases, 85 per cent. were over sixty years of age.

Proper treatment must include not only adequate reduction and fixation of the fracture, but also prompt and efficient preparation of the patient. It calls for close cooperation with the internist and the anaesthetist. It calls for the use of transfusions and vitamin therapy in the badly debilitated patient.

The problem of after-care is greatly simplified by the use of adequate internal fixation. The clinical judgment of the surgeon may be taxed severely in evaluating these cases. Should he operate or treat by traction? If operation is decided upon, should it be done as an emergency, or should a "cooling-off" period be permitted, so that supportive measures may be instituted to help the patient through the operation? How long should one wait?

We have had one bolt pull out of a combination Thornton plate and Smith-Petersen nail, and one plate which broke. Overdriving of the nail has not been a factor in our cases. We have been taught to try for a low position of the nail, whenever feasible. If the trochanteric block is intact, the nail alone is usually employed. If comminution is present or if the bone is very atrophic, a plate is used in addition.

There were only two cases of psychosis severe enough to require commitment. Toxic psychoses occurred infrequently.

Thrombophlebitis was a troublesome complication, and five deaths among our cases were ascribed to pulmonary embolism.

Pneumonia, cardiorenal disease, and uraemia were among the causes of death in this series. There were five cases of severe sepsis, either in wounds or in decubitus ulcers. Adhesive dermatitis was an annoying complication.

The end-result studies were as follows:

	No. of Cases	*Deaths*
1923 to 1940	158	41 (26 per cent.)
1941 to 1946	100	33 (33 per cent.)

The over-all mortality was 29 per cent.

In the earlier group of 158 cases, the following treatment was used:

Traction	98 cases
Plaster spicas	32 cases
Operation	5 cases
Bed rest	16 cases
Miscellaneous methods	7 cases

The second group of 100 cases (from 1941 to 1946) were treated as follows:

Traction (2 cases with spicas)	49 cases with 19 deaths (39 per cent. mortality)
Operation (internal fixation)	51 cases with 13 deaths (25 per cent. mortality)

The outcome in any given case will be determined in large measure by (1) the severity of the fracture, (2) the age and general condition of the patient, (3) the speed and finesse with which the fracture is reduced and maintained, and (4) the adequacy of the postoperative nursing care.

Dr. David Bosworth, New York, N. Y.: The nailing of these fractures is more difficult than the nailing of simple fractures of the neck. It is a hard job, and should be approached with care. Do not forget that there is a greater hospital mortality among the patients not operated upon, as well as a higher incidence of senility. The conversion of a patient with an intertrochanteric fracture from a tremendously depressed person to one who is comfortable is a spectacular thing. Open fixation is well worth while, and we use it always.

(*Continued on page 1082*)

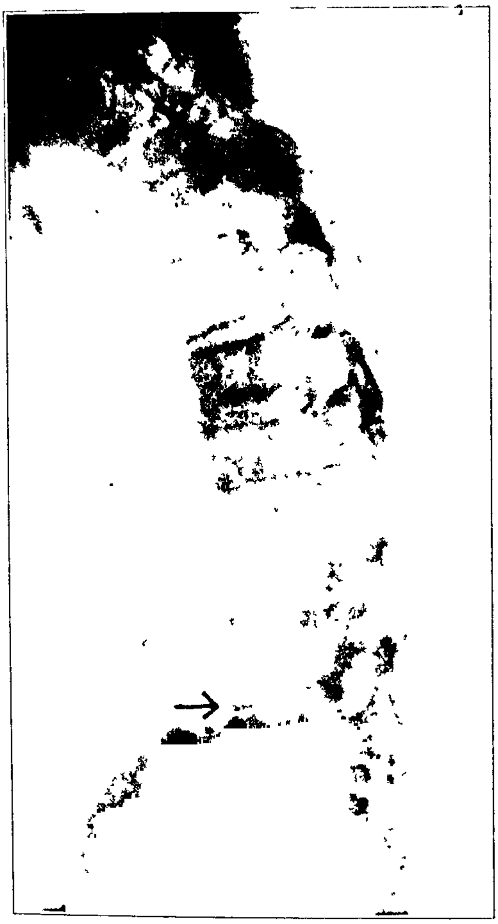

FIG. 4-A
Case 2, G. A. Preoperative roentgenogram.

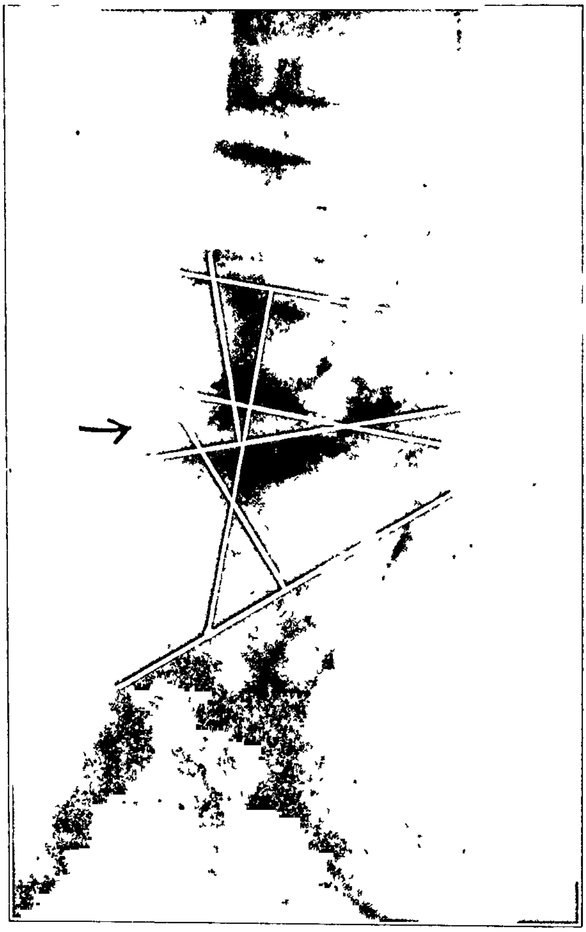

FIG. 4-B
Postoperative roentgenogram.

The patient is placed on the table in the prone position with sandbags and pillows on each side, so that the abdomen is not compressed by the weight of the body. This allows free diaphragmatic breathing and tends to reduce epidural hemorrhage.

A mid-line incision is made, and the tissues are reflected from the laminae, spinous processes, and articular processes by subperiosteal stripping. Exposure is made from the first sacral segment to the second lumbar. This facilitates the necessarily wide exposure. On identifying the site of osteotomy, assumed for description to be between the third and fourth lumbar vertebrae, the articular processes at that level are exposed, and the lateral borders of the third lamina are identified. A coronal section is then made with the osteotome and bone-cutting forceps through the spinous process of the third lumbar vertebra and directed so that ultimately the entire inferior articular process of this vertebra and some of the lamina superior to it will be removed. Another section is then made through the spinous process of the fourth lumbar vertebra and is directed obliquely cephalad toward the apex of the first section, so that a 45-degree wedge of bone will be removed with its base posterior. This wedge will ultimately include the superior articular process of the fourth lumbar vertebra and some of the superior portion of its pedicle. This section of bone, which is usually somewhat decalcified and may be sectioned and curetted with ease, is then broken out down to the ligamentum flavum, which is usually well calcified. The ligamentum flavum is then removed, exposing the dura and the nerve roots at that level. With osteotome and curettes, the remainder of the articular processes and a portion of the pedicle below on each side are removed, which completes the wide foraminotomy and gives a thorough exposure of the nerve roots. Epidural bleeding must be controlled.

TABLE I

SITE OF FRACTURE-DISLOCATION OF THORACOLUMBAR SPINE IN FORTY-THREE CASES

Vertebrae Involved	Number of Cases
Eighth and ninth thoracic vertebrae	1
Ninth and tenth thoracic vertebrae	1
Eleventh and twelfth thoracic vertebrae	13
Twelfth thoracic and first lumbar vertebrae	17
First and second lumbar vertebrae	6
Second and third lumbar vertebrae	2
Third and fourth lumbar vertebrae	2
Fourth and fifth lumbar vertebrae	1

the hospital as a compression fracture of the second lumbar vertebra; the following day, under a general anaesthetic, the patient was treated by hyperextension and plaster-of-Paris. When he recovered from the anaesthetic, he had a complete paraplegia. Within four hours of this treatment, an open reduction of a fracture-dislocation between the first and second lumbar vertebrae was performed; and, apart from some weakness of the dorsiflexors of his left foot, the patient has made a complete recovery from the paraplegia This recovery commenced within four days of the reduction. This mistake was due to bad roentgenography and also to faulty interpretation of the plates (Figs. 3-A to 3-H, inclusive).

RESULTS

Closed Reduction

Of the five cases with complete paraplegia treated by the closed method (Table III), one patient made a complete recovery, is back at light work, and is a wrestler of some repute. Another made a partial recovery, has good hip and knee control, but a bilateral paralytic talipes calcaneus; after surgical treatment for this, he will be able to walk again (Figs 4-A to 4-E, inclusive). A third patient showed some early promise, and within four months had partial sensory and motor recovery in both lower limbs; he was able to take a few steps before it was necessary to evacuate him because of war conditions. He died very recently; unfortunately an examination was not possible before his death, but he apparently made no further recovery after leaving the hospital. No details concerning the other two patients can be given, as they were not treated by the writer. There is no record that reduction was successful, nor did any recovery occur.

One patient with partial paraplegia was treated by manipulative reduction, and made an almost complete recovery. Apart from bilateral drop-foot, he has good voluntary control of all muscles. Roentgenograms show that reduction is good, and spontaneous fusion of the two affected vertebrae has occurred He is doing light work.

The four patients with no paraplegia were treated by hyperextension and plaster, presumably under the impression that they had compression fractures. No disasters resulted, as might have been expected. Indeed, in one case reduction was accomplished by this method, but the spine has subsequently become displaced again. All four patients are sufficiently fit to do light work.

TABLE II

DEGREE OF PARAPLEGIA COMPLICATING THORACOLUMBAR FRACTURE-DISLOCATIONS

Paraplegia	Number of Cases
None	8
Partial	3
Complete	27
None, becoming complete	1
Partial, becoming complete	2
Partial, disappearing on or before admission (based on statement of patient)	2

Open Reduction

The results in those patients treated by open operation have been very disappointing. Of eighteen patients with complete paraplegia, only one has made an almost complete recovery from the nerve injury. He was the patient mentioned previously, in whom a complete paraplegia developed after treatment of an uncomplicated fracture-dislocation

Fig. 3-A

Fig. 3-B

Case 4, B. C. This patient had a fracture-dislocation between the first and second lumbar vertebrae, with interlocking of the articular facets and lateral shift.
Figs. 3-A and 3-B: Before reduction.

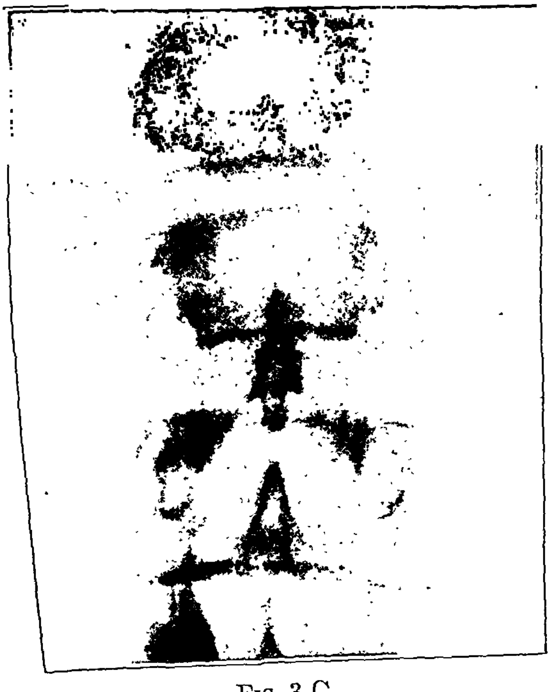

Fig. 3-C

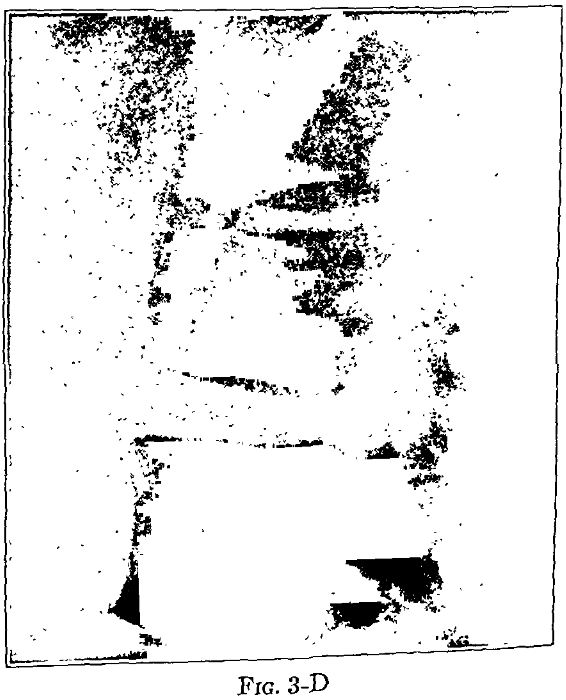

Fig. 3-D

Immediately after reduction.

The pillows and sandbags are next removed, and downward pressure is made on the lumbar spine by the operator. A certain amount of "give" takes place with steady pressure. Frequently a firm thrust has to be made, which is usually followed by a snap, when the anterior longitudinal ligament ruptures. At this point the correction is apparent and is maintained. The contiguous borders of the vertebrae are now in contact.

During this manoeuvre, one has the impression that the lamina of the superior vertebra is angulating and is compressing the dura to an alarming degree. This phenomenon may be safely ignored, since we have found no evidence of compression of the dura and cauda equina at this point. The remnants of the laminae of the third and fourth lumbar vertebrae are then denuded of outer cortex by osteotomes, leaving a raw, bleeding, bony surface. A stainless-steel curved spine plate, as designed by Wilson[4], is then placed in a bony trough along the lateral surface of the spinous processes on the right side and is secured by means of bolts and elastic stop nuts to the spinous processes of the second and fifth lumbar vertebrae. (We have found that ordinary nuts tend to loosen and unwind.) Bone chips, prepared from the sections of bone previously removed, are then packed into the denuded laminal troughs on both sides of the spinous processes to effect a bony fusion between the third and fourth lumbar vertebrae, as described by Briggs and Milligan. The wound is then carefully closed in layers.

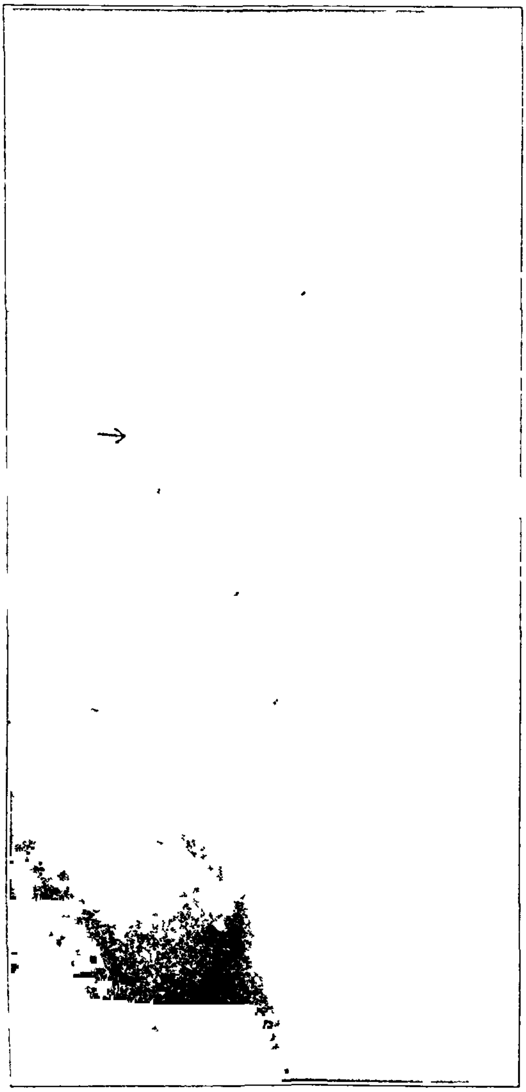

FIG. 5-A

Case 3, D. R. Roentgenogram taken before operation.

FIG. 5-B

Roentgenogram taken after operation.

TABLE I

Occurrence of Tardy Paralysis of Ulnar Nerve According to Occupation

Occupation	No. of Patients
Professional and managerial	17
Clerical and sales	21
Service	21
Agriculture, fishing, forestry, and mining	24
Skilled labor	12
Semiskilled labor	0
Unskilled labor	5
Total	100

Tardy paralysis of the ulnar nerve was found to be a disease of adult life. The average age of a patient was thirty-eight years. Seventy-five per cent. of all the patients were more than thirty years old; only five were found who were less than twenty years old. The youngest patient was sixteen years old and the oldest, seventy-three years.

Men were more frequently afflicted with this condition than women by a ratio of four to one.

Tardy paralysis of the ulnar nerve did not appear to be especially likely to develop among members of any particular occupational group. Just as many so-called "white-collar" workers had this disease as persons engaged in heavy physical labor (Table I).

The right hand was most commonly affected. In 53 per cent. of the cases, paralysis occurred on the right; in 36 per cent., paralysis occurred on the left; the condition was present bilaterally in 11 per cent. of the cases. In all of the cases in this series, paralysis was caused by disease or injury which affected the ulnar nerve in the region of the elbow joint.

An old fracture of the elbow was the leading pathological condition which caused tardy paralysis of the ulnar nerve (Table II). More than three fourths of the fractures involved the humerus; and the lateral condyle was the specific site in about half of the cases of fracture (Fig. 1). In every case of fracture, there was a history of injury. The average interval between the injury and the onset of symptoms was twenty-two years. The shortest interval was four months; the longest was sixty years.

Arthritis was the causative factor in 20 per cent. of the cases. In this group, two thirds of the patients gave no history of injury to the elbow. One patient had old gonococcal arthritis which involved the elbow joint; another had chronic arthritis, involving other joints in addition to the elbow.

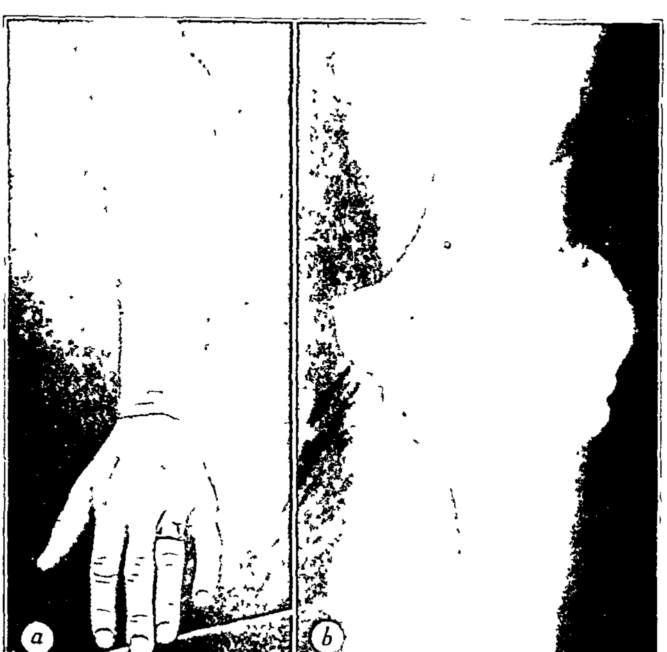

Fig. 1

Fig. 1, *a:* Left arm and hand of patient who had tardy paralysis of the ulnar nerve, demonstrating cubitus valgus, prominence of the lateral condyle of the humerus, and effects of atrophy of the intrinsic muscles of the hand. The condition was caused by an old fracture of the lateral condyle of the humerus, with non-union of fragments.

Fig. 1, *b:* Anteroposterior view of the left elbow.

During the operation, the patient is maintained on a continuous infusion of 5 per cent. glucose in saline; and a transfusion of 500 cubic centimeters of whole blood is at hand. After operation, the patient is placed in a supine position. After four to five days, a long Taylor spine brace is applied, which the patient wears at all times. After ten to fourteen days, the patient is permitted to be ambulatory and is advised to wear the brace continuously for a year or longer.

The technique as described represents the product of our cumulative experiences. Although this operation is a formidable procedure, it is technically feasible for one who is familiar with disc surgery.

CASE REPORTS

Case 1. K. D. B., a white male, aged twenty-one, with a flexion deformity (Fig. 3-A) of five years' known duration, was operated upon February 28, 1945. Osteotomy of the spine was performed between the fourth and fifth lumbar vertebrae, with bony fusion of these segments (Fig. 3-B). The patient returned voluntarily for examination on January 8, 1946. He felt well and had no pain. Correction was well maintained. The patient was very well pleased with the improvement in his posture. The result was classified as excellent.

In this case, our first, we feared that we might have gained too much correction, and that, when fusion had occurred, the head might be tipped too far backward, and the patient might not be able to look directly forward. About a week after operation, a Taylor brace was applied, and the patient was helped to a standing position at the side of the bed. It was then noted that his posture was entirely satisfactory.

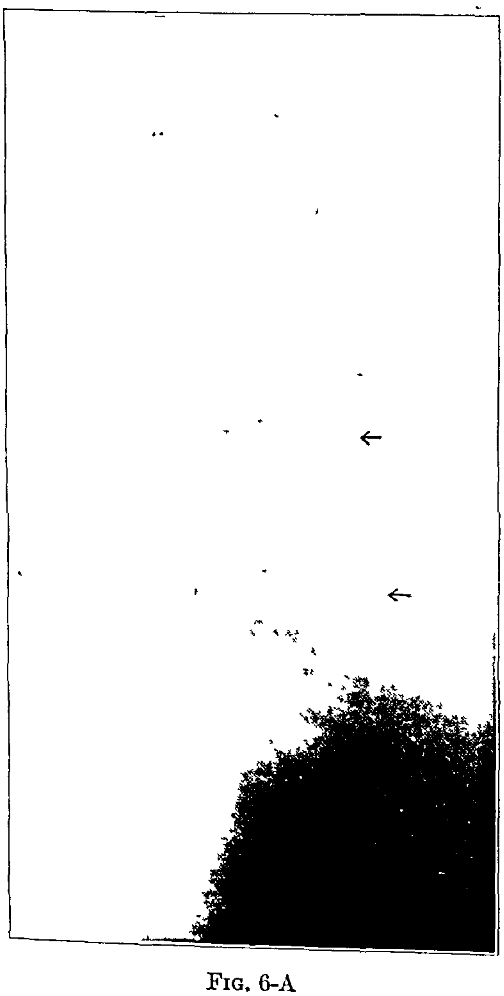

Fig. 6-A
Case 4, T. T. Preoperative roentgenogram.

Fig. 6-B
Postoperative roentgenogram.

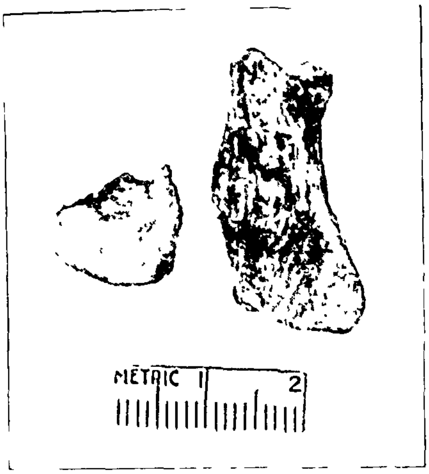

FIG. 2-A

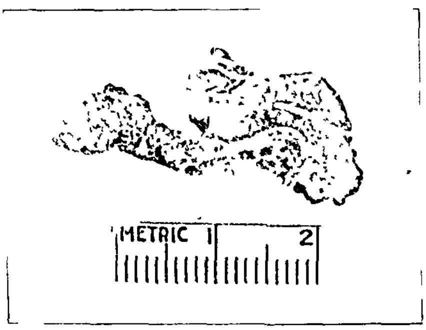

FIG. 3

FIG. 2-B

Fig. 2-A: Neuroma of the ulnar nerve removed from a patient (Case 8) who had tardy paralysis of the ulnar type. Proliferation of fibrous tissue had destroyed most of the nerve fibers.

Fig. 2-B: Section of the neuroma, removed from this patient. The few normal nerve fibers present are surrounded by dense fibrous tissue (Mallory phosphotungstic hematoxylin) (× 8).

Fig. 3: Multilocular ganglion cyst, arising from tendon in the olecranon fossa, which compressed the ulnar nerve and resulted in tardy paralysis of the nerve (Case 7).

TABLE II

ETIOLOGY OF TARDY PARALYSIS OF ULNAR NERVE

Cause	No. of Patients
Old fracture of elbow	57
Arthritis of elbow	20
Unknown	12
Occupational trauma of elbow	4
Congenital anomalies	3
Adhesions secondary to elbow injury	2
Cyst of elbow	1
Recurrent dislocation of elbow	1
Total	100

The majority of these patients, however, had hypertrophic arthritis of the elbow of unknown cause. Trauma of the ulnar nerve in the group with arthritis was caused by obliteration of the ulnar groove, which stretched and displaced the nerve, or by direct irritation in the form of spurs or loose bodies.

Twelve per cent. of the patients had no abnormality to account for the presence of tardy paralysis of the ulnar nerve.

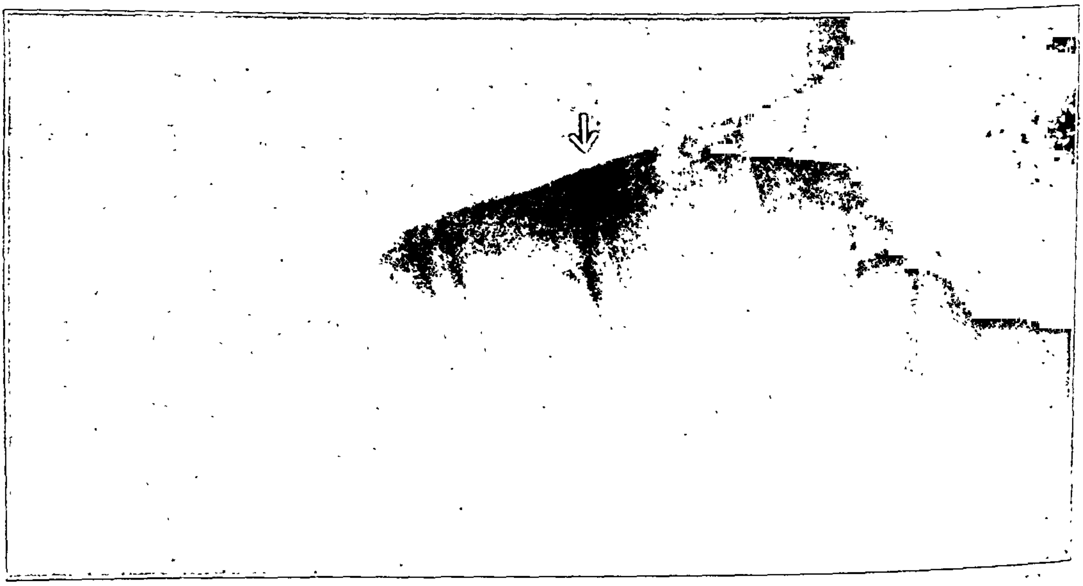

Fig. 7-A

Fig. 7-A: Case 5, M. N. Preoperative roentgenogram.

Fig. 7-B

Fig. 7-C

Figs. 7-B and 7-C: Roentgenograms taken after operation.

TABLE III

SYMPTOMS IN ORDER OF FREQUENCY

Symptom	Occurrence (No. of Times)
Paraesthesia	85
Atrophy	81
Paralysis	62
Pain	39
Anaesthesia	25
Fibrillation	7
Tremor	3

In the remaining cases (11 per cent.), the disease was caused by miscellaneous conditions, such as congenital anomalies, occupational trauma, adhesions, ganglion cyst, and recurrent dislocations of the elbow joint.

PATHOLOGICAL ASPECTS

In most of the cases studied, a fusiform neuroma of the ulnar nerve was found at operation. Since the accepted treatment is transplantation without resection of the nerve, little information was available as to the microscopic pathological aspects of the affected nerve. One patient died from causes not related to this report, and the transplanted nerve was removed at necropsy. In another patient a large neuroma was removed, and end-to-end anastomosis of the nerve was performed. The gross and microscopic observations in this case are illustrated in Figures 2-A and 2-B.

According to Conway, the early stage of involvement consists of hyperaemia and oedema of the nerve. This is followed at a later stage by an increase in fibrous tissue. During this vicious process of hyperaemia, oedema, and proliferation of fibrous tissue which compresses the nerve fibers, the motor fibers appear to be more vulnerable than the sensory fibers. It must be assumed, in view of the favorable course in most of these patients, that removal of the source of trauma reverses the pathological process, in spite of the presence of a neuroma at the time of operation.

DIAGNOSIS

Probably the most characteristic feature of tardy paralysis of the ulnar nerve, other than its delayed appearance after trauma, is the development of profound atrophy of the intrinsic muscles of the hand, with relatively little or late impairment of sensation. Since wasting of the muscles in a hand is especially noticeable to a patient, most of the patients reported for treatment, even though they had only moderate disability from this condition. It was estimated that slightly more than half of the patients (51 per cent.) had 50 per cent. or less disability, as judged by the interference caused by their symptoms in the performance of their normal daily activities.

The average duration of symptoms was 2.9 years. The shortest duration in this series was two weeks; the longest, thirty-nine years. More than half of the patients had had symptoms for less than two years.

The predominating symptoms, in order of frequency, were paraesthesia, atrophy, and paralysis referable to the hand. Only a third of the patients complained of pain. Anaesthesia was a complaint in less than a fourth of the cases. Fibrillations and tremors were rarely observed by the patients (Table III).

On physical examination, the most common observations were atrophy and weakness of the hand; these were present in 96 per cent. of the cases (Table IV). Three fourths of the patients had an ulnar type of anaesthesia in the hand. Half of the patients had an

CASE 2. G. A., a white male, aged thirty-six, with a deformity of about eight years' duration (Fig. 4-A), underwent an osteotomy of the spine, on May 19, 1945, involving the fourth and fifth lumbar vertebrae, with chip fusion of these segments (Fig. 4-B). When again examined, November 12, 1946, he seemed to have gained weight and had no pain or discomfort although he appeared to have lost some of the correction. Ankylosis of the hips was progressing, and he was using a cane. At that time, he was employed as an inventory clerk. The result of the operation was classified as fair.

In this case, the correction at the operation seemed to be adequate, although no snap of the anterior longitudinal ligament was heard. Roentgenograms taken immediately after the operation showed a 34-degree correction. A spine plate was not used. Roentgenograms taken eighteen months later showed almost complete loss of correction. This indicated that, unless the anterior longitudinal ligament ruptures, correction cannot be maintained without internal fixation.

CASE 3. D. R., a thirty-year-old white male, had a deformity of eight years' known duration. A lumbosacral fusion for a painful back had been performed three years previously at another hospital. One of the preoperative roentgenograms is shown in Figure 5-A. On November 14, 1945, osteotomy of the spine was performed between the third and fourth lumbar vertebrae, with chip fusion of these vertebrae. A spine plate of the Wilson type was applied to the spinous processes (Fig. 5-B). The patient was again examined November 12, 1946. At that time, he was working as an assembler. He had some pain at the upper end of the incision and felt that he was losing the correction, although he appeared to have retained some of the initial correction. The result was classified as fair.

In this case, in spite of a vigorous downward thrust, with the head and foot of the table elevated, no snap was heard or felt, and the back seemed to spring back to its original position when the pressure was released. For this reason, a spine plate was applied. Roentgenograms showed that some correction had been obtained, but it has not been maintained. The site of osteotomy in this case was not chosen where the anterior longitudinal ligament was well calcified. Because of this experience, we now feel that the osteotomy site should be chosen where the ligament is well calcified.

CASE 4. T. T., a colored female, aged twenty, with a known duration of symptoms of two years (Fig. 6-A), was operated upon January 16, 1946. Osteotomy of the spine was performed between the third and fourth and the fourth and fifth lumbar vertebrae, with bony chip fusion from the third to the fifth lumbar vertebrae (Fig. 6-B). On November 12, 1946, the patient had no pain. Correction had been maintained, despite a fall from the second-story window two months postoperatively. The patient was pleased with the result of the operation.

This back was corrected very easily at operation, and a snap, indicating that the anterior longitudinal ligament had ruptured, was heard. When the correction had been obtained, it appeared that the lamina of the fourth lumbar vertebra was angulating downwards, compressing the cauda equina. This situation had been noted before. To check the condition, the whole fourth lamina was slowly removed, but no actual compression of the dura by the border of this lamina could be found. After the operation, the patient was watched carefully for evidence of root compression, but gave no indication of such compression.

CASE 5. M. N., a white male, aged thirty-eight, had a deformity of fourteen years' known duration (Fig. 7-A). On May 22, 1946, osteotomy of the spine was performed between the third and fourth lumbar vertebrae and a spine plate was applied, with subsequent bony fusion of the vertebrae (Figs. 7-B and 7-C). When examined on November 12, 1946, the patient was considerably improved. Correction had been maintained, and the patient was working in a gasoline filling station. He had no pain and was well satisfied with the improvement in his posture. The result was classified as excellent.

When the anterior longitudinal ligament ruptures, as in this case, one is impressed by the instability of the spine and the possibility of the slipping of one vertebra on the other at the osteotomy site. This seemed to be a dangerous situation, because of the possibility of injury to the cauda equina. However, as soon as the Wilson-type spine plate had been applied, stabilization of the involved segments was established. The value of internal fixation was then very apparent.

TABLE IV

PHYSICAL FINDINGS IN ORDER OF FREQUENCY

Finding	Occurrence (No. of Times)
Atrophy	96
Weakness	96
Anaesthesia	77
Enlarged nerve	51
Limited motion of elbow	48
Hypotonia	42
Deformity of elbow	39
Tender nerve	35
Tremor	9
Fibrillation	7
Shallow ulnar groove	8
Mass near ulnar groove	2
Painful elbow motions	1
Bilateral cervical ribs	*1*
Involvement of median nerve	1

enlarged ulnar nerve, but few of these patients had nerve tenderness. There was limitation of motion of the elbow joint in slightly less than half of the cases. Other observations frequently made were hypotonia of the muscles and gross deformity of the elbow. Tremor, fibrillation, a shallow ulnar groove, a palpable mass in the olecranon fossa, and pain on motion of the elbow were observed infrequently. In one case the concomitant finding of bilateral cervical ribs, and in another a simultaneous involvement of the median nerve, complicated the diagnostic pattern.

A study of these cases indicated that tardy paralysis of the ulnar nerve should be suspected in any case in which a patient complains of paraesthesia of ulnar distribution and exhibits wasting of the intrinsic muscles of the hand, regardless of whether or not sensory disturbances are present. The region of the elbow should be observed carefully, palpated, and manipulated in the search for pathological conditions which might account for dysfunction of the ulnar nerve. In this series, roentgenograms of the elbow joint were important, since many of the etiological factors were demonstrated prior to operation only by this means.

The principal conditions which may be confused with tardy paralysis of the ulnar nerve are the scalenus anterior syndrome, hypothenar neural atrophy[5], various intraspinal lesions, syringomyelia, and progressive muscle atrophy. Most of these conditions can be eliminated effectively by careful performance of physical and neurological examinations, and by evaluation of the results. The hypothenar neural atrophy described by Hunt deserves special mention. This condition is caused by chronic pressure on the deep palmar branch of the ulnar nerve. This branch is purely motor in function, and the paralysis is slowly progressive without sensory impairment. This is invariably an occupational disease.

PROPHYLAXIS

Tardy paralysis of the ulnar nerve could have been prevented in many of the cases in which a fracture of the elbow joint was the underlying cause. Prophylaxis would have involved more serious consideration of the injury to the elbow at the time it occurred.

Many of the fractures were either unrecognized or were inadequately treated. A typical history included a fall in childhood, which resulted in a bruised, swollen, and painful elbow. Usually, roentgenograms had not been taken, and the therapeutic program had consisted of the application of heat or cold, rest, and support of the injured arm across

This operation was performed by the technique described, with a successful result, as demonstrated by the roentgenograms. We encountered some immediate difficulty in this case; the patient was placed on his back following the operation, and every time he was turned onto his side, he showed respiratory embarrassment and had to be turned immediately onto his back. This seemed to be due to pressure on the abdomen and interference with abdominal breathing.

Patients with severe ankylosing arthritis of the spine have very little, if any, excursion of the thoracic cage in respiration, and any changes in intra-abdominal pressure, which might interfere with diaphragmatic motion, are dangerous. This case indicates the importance of maintaining the patient in the supine position postoperatively.

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DISCUSSION

(Continued from page 1067)

Dr. J. Albert Key, St. Louis, Missouri: In our series at the St. Louis City Hospital, the mortality of trochanteric fractures was 43 per cent. when we treated these cases conservatively. When I first started, I thought I could nail a trochanteric fracture as I would a fractured neck. This procedure must be carried out on a fracture table. The fracture must be reduced by mechanical traction, and the reduction must be checked with the roentgenogram, which is easier than in the case of the fractured neck, because the extremity can be brought out to the plate. The operation can be most easily carried out under general anaesthesia, and the mortality will be less than that obtained with conservative treatment.

Dr. Frederick R. Thompson, New York, N. Y. (closing): I have very little to add except to thank the discussors,—Drs. Diveley, Norton, Bosworth, and Key. We did not operate upon these patients with fractures under traction. We used the usual operating table. Although many fractures can be reduced by manipulating the lower extremity before operation, some require reduction at the time of operation.

the chest in pronation and acute flexion. Some degree of limitation of elbow motion had persisted, and ulnar paralysis had appeared insidiously in adult life.

In the treatment of recent fractures, it is suggested that, if open reduction is indicated and the surgeon anticipates a deformity of the elbow, prophylactic transplantation of the ulnar nerve may be performed at the same operation.

In the group of cases without fracture, the underlying pathological process was obscure to the patient; no prophylactic treatment was suggested by a study of these cases.

One case is reported here (Case 10) in which the only etiological factor was chronic occupational trauma. The patient was an accountant, who habitually rested his elbow on a desk. He was instructed to protect his ulnar nerve from such trauma and to perform restorative exercises of muscles supplied by the ulnar nerve. In this case, operation was avoided.

During long surgical procedures, with the patient in a supine position, it is a good technique to place small pillows between the patient's elbows and the operating table. This measure will prevent injury to the ulnar nerve.

TREATMENT

In general, the course of tardy paralysis of the ulnar nerve is characterized by unrelenting progression, and no known conservative form of treatment has been found to be of any permanent benefit. Best has written a good summary of the various forms of surgical treatment which have been employed. The following operations have been designed to prevent stretching of the nerve, to relieve sources of direct irritation, or to reverse the process of formation of neuroma.

The first operation is supracondylar osteotomy, which was adopted to shorten the humerus and to relieve pathological stretching of the nerve at the elbow. This was a formidable procedure which did not always accomplish its intended purpose, because of postoperative involvement of the nerve in scar tissue or the formation of osteoma.

The second operation is deepening of the ulnar groove, a procedure introduced to reduce tension of the nerve. This operation failed because the postoperative development of osteoma often obliterated the groove. Scar tissue then added insult to the nerve.

The third procedure consists of removal of bone fragments and loose osteocartilaginous bodies. This was designed to remove the source of direct irritation of the nerve. It proved to be an inadequate attack on the problem, unless the nerve was transplanted anteriorly at the same time. Additional loose bodies were especially likely to recur, and the damaged nerve did not recover unless maximum protection against stretching was provided.

The fourth operation is transplantation of the nerve anterior to the medial epicondyle of the humerus. This procedure has withstood the test of time. Most forms of trauma to the nerve at the elbow are relieved by this method. Flexion of the forearm in the presence of a deformed elbow causes pathological stretching of the ulnar nerve. After this operation, flexion of the elbow actually reduces tension on the nerve trunk. In addition, this method places the nerve at a distance from other sources of irritation at the elbow. The procedure introduced by Murphy[6, 7] consists of transplantation of the nerve into the subcutaneous tissue and its envelopment in a tube of fat and fascia. This technique provides fair results. The damaged nerve is readily traumatized, however, since the skin and subcutaneous tissues offer inadequate protection. Adson developed a method of transplantation of the nerve into a muscle bed. This was accomplished by sectioning the anterior portion of the adjacent flexor or pronator muscles of the forearm, and resuturing the muscles over the nerve trunk. This procedure offers better protection for the injured nerve, and has provided the most favorable results. The details of the technique were reported by Adson in 1918.*

* Suspension of the nerve in a sheath of fascia lata no longer is done. Otherwise, the Adson technique is followed.

CONGENITAL DISLOCATION OF THE PATELLA

Case Report with History of Four Generations

BY E. B. MUMFORD, M.D., INDIANAPOLIS, INDIANA

It is not the purpose of this discussion of a congenital dislocation of the patella to give a historical review of the anatomical and embryological factors which differentiate the congenital type of dislocation, a constant condition, from the recurrent type of dislocation, a changing condition. These phases of the subject have been covered thoroughly by Conn in his carefully prepared presentation of a plan of operation for the congenital type of dislocation.

Conn does not give a detailed description of the changes, if any, noted in the knee joint at the time of operation. His comment on this phase of the study was: "The exposed capsule revealed a small patella lying with its articular surface apposed to the lateral surface of the external femoral condyle, in which position it was anchored by the shortened fibers of the external capsule". The roentgenogram was essentially negative.

That changes within the internal structure of the knee joint may occur, especially in old cases, may be seen from Figures 1-A and 1-B (a left knee) and Figures 2-A and 2-B (a right knee). These two cases represent the congenital type of dislocation; some pain had been present since early childhood. Each was a female, one sixty years and one seventy years of age. Each refused an operation. The changes seen in Figures 1-A and 1-B are very extensive, and show not only progressive changes in the femoral and tibial condyles, resulting from a long period of faulty weight-bearing, but also osteochondritic changes, with the formation of loose bodies and a thinning of the articular cartilage.

CASE REPORT

V. M., a white woman, aged twenty-five and in good health, was first seen by the author on July 1, 1936. Her complaint was pain and instability in each knee. She gave the following history: The first time she could remember having trouble with her knees was between the ages of six and seven. She was a very healthy child, and strong in every way except for her knees. She would try to play games with the other children, but could not always do so. For a week she might not have any trouble, and then she would have pain and instability

Fig. 1-A Fig. 1-B

Congenital dislocation of left patella in M. C., a woman, sixty years of age.

TABLE V

SUMMARY OF TREATMENT IN 99 OF 100 CASES *

Surgical Procedure	No. of Times Employed
Anterior transplantation of ulnar nerve into intramuscular bed	95
Anterior transplantation of ulnar nerve into subcutaneous bed	4
Neurolysis	54
Removal of callus or of loose bodies	10
Drainage of wound	5
Release of adhesions	3
Application of cast	1
Freeing of median nerve	1
Removal of ganglion cyst	1
Manipulation of elbow	1
Section of anomalous artery and vein	1
Excision of neuroma and end-to-end anastomosis	1

* One patient was treated conservatively.

The fifth operation is neurolysis, performed to check the formation of neuroma. This procedure has a considerable empirical basis, in that severing or stretching of the tense transverse fascial fibers should relieve compression of the nerve fibers within the neuroma. The most common form of neurolysis consists in the making of longitudinal incisions in the outer connective-tissue layers of the neuroma. This is done at regular intervals in the circumference of the mass by the use of a sharp safety-razor blade. Another type of neurolysis consists of distending the nerve sheath by the injection of saline solution. The principle of this procedure is to stretch the transverse fibers over the neuroma. It would seem that this procedure would be less effective, since the stretching effect probably is nullified by the increased pressure within the mass.

The sixth procedure is resection of the neuroma and the performance of end-to-end anastomosis of the nerve ends. This procedure is carried out on the assumption that the neuroma actually is a tumor which permanently inhibits the return of nerve function. There is evidence in the literature and in the present study, however, to indicate that the size of the neuroma has little bearing on the degree of recovery which will be obtained after the primary causative factors have been eliminated. In only one case in this study was resection of the neuroma and end-to-end anastomosis performed. In this case, the patient had a neuroma of such unusual size that the nerve could not be manipulated or transplanted easily.

The seventh operation consists of combinations of the afore-mentioned treatments. The most common combination which was used in the present series of cases consists of anterior transplantation of the nerve into a muscle bed, neurolysis of the neuroma by multiple longitudinal incisions, and, occasionally, removal of a loose osteocartilaginous body.

The eighth procedure consists of a special attack on anomalous conditions, occasionally encountered. The best examples of cases in this study in which special techniques were utilized were the finding of an anomalous artery and vein, which compressed the ulnar nerve at the elbow, and a ganglion cyst which arose from the tendon and compressed the nerve (Fig. 3).

In the present study, 95 per cent. of the patients were treated by anterior transplantation of the nerve into a muscle bed. Subcutaneous transplantation was used in only 4 per cent. of the cases. Neurolysis was performed in 54 per cent. of the cases; and, in 10 per cent., loose bodies were taken out or callus was removed. A variety of other procedures,

CHART I

History of Maternal Relatives of Patient

- Grandmother (Patellae dislocated)
  - Four Uncles (All normal)
  - Oldest Aunt (Patellae dislocated)
  - Middle Aunt (Patellae normal)
  - Mother (Patellae dislocated)
    - Oldest Sister (Patellae dislocated)
      - First Daughter (Died in infancy)
      - Second Daughter (Normal)
      - Third Daughter (Very bad knees)
    - Middle Sister (Patellae normal)
    - Patient (Patellae dislocated)
      - Son (Normal knees)

in each knee, day after day. At times, when the knee would turn to the side, it would hurt so much that she could not play and had difficulty in walking, but there would not be any swelling. At other times, she would fall, the knee would become swollen, and she could not walk for a long time. The amount of injury seemed to be related to the position of the legs at the time of the fall. As she grew older her knees turned more and more and her legs became weaker, so that she could scarcely walk without falling. At the time of the examination, she had to use crutches.

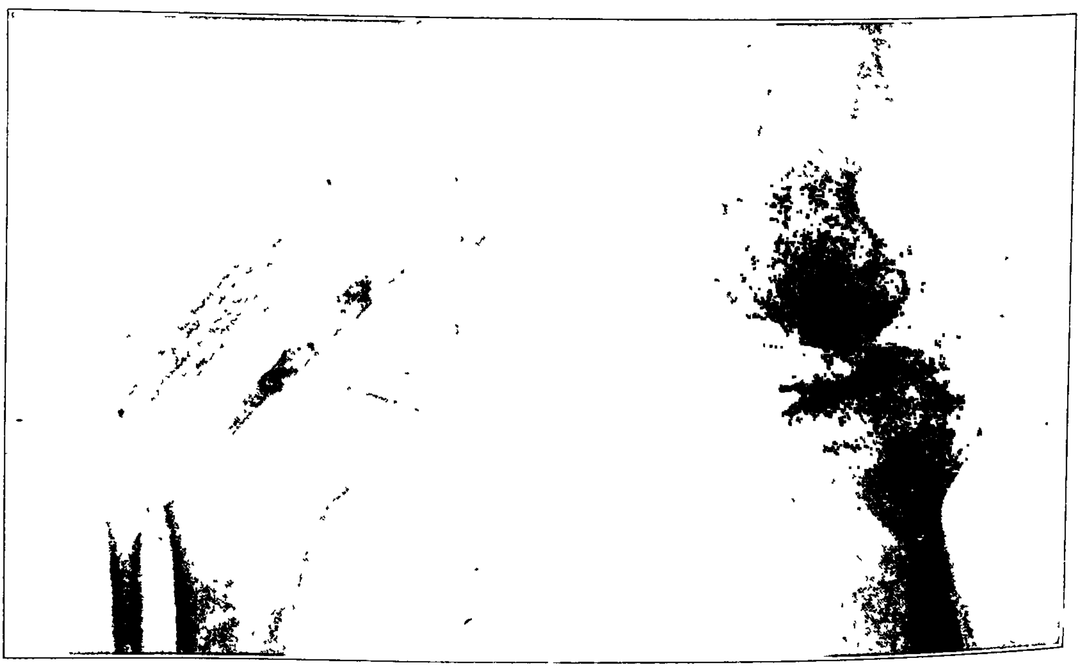

Fig. 2-A Fig. 2-B

Congenital dislocation of right patella in O. T., a woman, seventy years of age.

which were instituted in addition to anterior transplantation of the nerve, are indicated in Table V.

Ether, administered by the open-drop method, was the anaesthetic agent chosen in 80 per cent. of the cases. In 14 per cent., brachial-plexus block anaesthesia was employed, and three patients in this group required some other type of anaesthetic as a supplement. A patient was rarely operated upon under pentothal-sodium or nitrous-oxide anaesthesia.

Davidson and Horwitz, as well as other authors, have recommended a vigorous program of physiotherapy after operative treatment. In the cases reported in this study, no special physiotherapy program was employed. Patients were instructed to use the arm and hand normally, but to avoid flexing the elbow against resistance, such as lifting or pushing a heavy object, for a period of three months. This advice was given to avoid tearing the common flexor attachment from the medial epicondyle, where it had been reattached by sutures at operation.

RESULTS

The results of surgical treatment for this condition were gratifying. In the 100 consecutive cases studied, 70 per cent. of the patients obtained a satisfactory result. This was judged by information which indicated that the patient was able to participate in his normal activities, that he had regained normal use of his hand, and that he was satisfied with the result. This information was obtained by re-examination of the patients at the Mayo Clinic (twenty cases), by adequate reply of the patients to a detailed questionnaire (forty-three cases), or by reports from the patients or their family physicians which contained sufficient details to make it possible to judge fairly the results of treatment (thirteen cases).

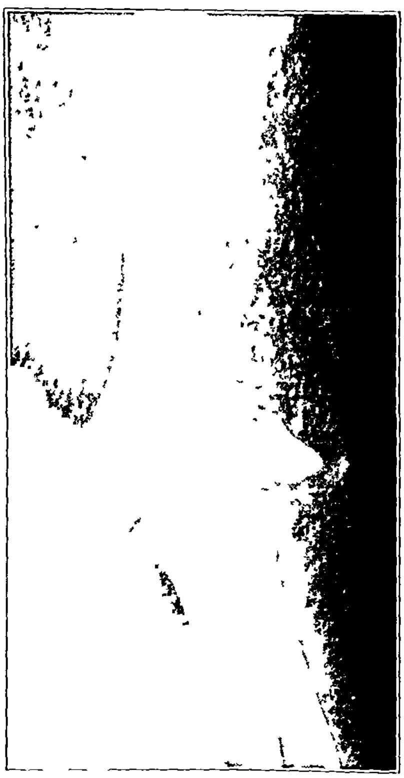

FIG. 4

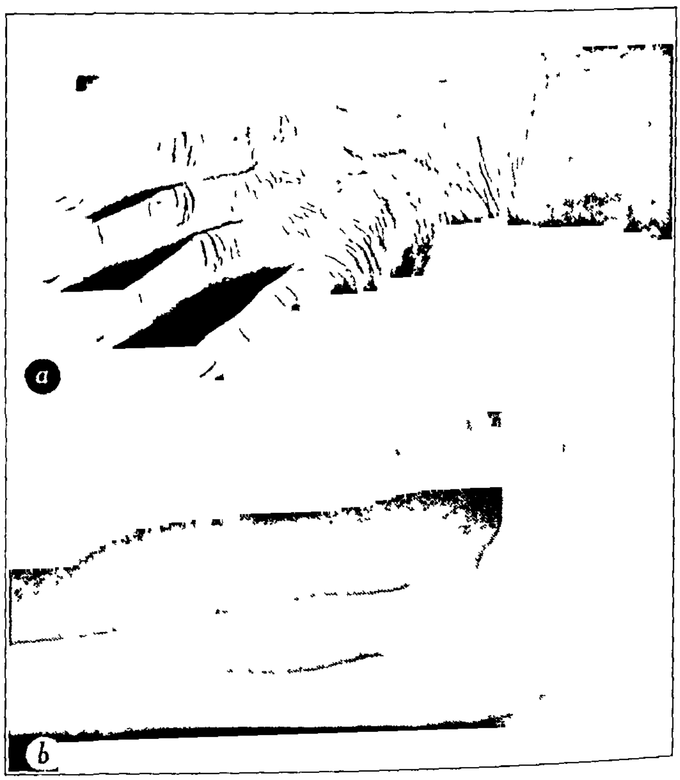

FIG. 5

Fig. 4: Anteroposterior view of the right elbow joint of a patient (Case 1) with tardy paralysis of the ulnar nerve. There was an old intra-articular fracture of the lateral condyle of the right humerus, with non-union of the fragment, which was displaced anteriorly.

Fig. 5, *a:* Left hand of a patient (Case 6) who had tardy paralysis of the ulnar nerve. Shows effects of atrophy of the intrinsic muscles of the hand.

Fig. 5, *b:* Lateral view shows moderate hypertrophic arthritis of the elbow joint, with spur formation.

Family History: In this unusual family history a "knee condition" existed in four successive generations (Chart I), and was described by the patient as being similar to that of her own knees. (None of the other members of the family were seen by the author.) All of the knee conditions occurred in the females, and none in the four males of the second generation (uncles of the patient) or in the patient's son (fourth generation). In both the second and third generations there were three females, but the knee condition was present in only the oldest and the youngest of each of these generations, the middle female having normal knees. In the fourth generation, the youngest daughter has "very bad knees".

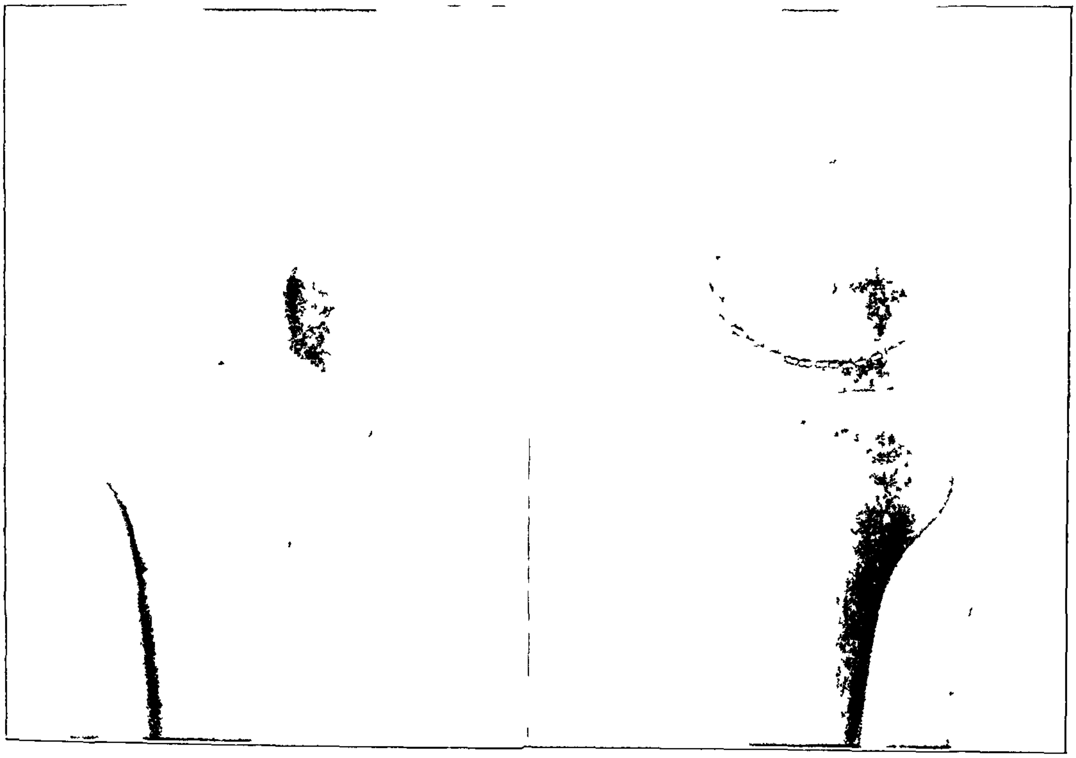

FIG. 3-A

Roentgenograms of V. M., aged twenty-five, taken before operation.

FIG. 3-B

Postoperative roentgenograms of same patient, taken on April 25, 1938.

Thirty-seven patients who obtained satisfactory results had residual symptoms which consisted chiefly of anaesthesia and paraesthesia. A few patients had some degree of pain, atrophy, or weakness. None of these symptoms were severe; all of them occurred intermittently and were precipitated by fatigue, arising from heavy work.

Six patients were not benefited by surgical treatment. One of these patients was treated by subcutaneous anterior transplantation of the nerve, and another underwent excision of a neuroma and end-to-end anastomosis of the ulnar nerve, in addition to intramuscular anterior transplantation of the nerve.

No information was available in twenty-four cases.

REPORT OF CASES

CASE 1. A housewife, forty-two years old, had sustained a fall and had suffered a fracture of the right elbow joint fourteen years prior to the onset of ulnar palsy. The extremity had been immobilized in acute flexion, and the patient had not regained full use of her arm for more than a year. Fourteen years after the accident, she had begun to experience paraesthesia and numbness over the distribution of the ulnar nerve in her right hand. This condition had progressed slowly, and her household activities had had to be seriously curtailed. On examination, she exhibited complete ulnar paralysis on the right. A roentgenogram of the right elbow disclosed an old intra-articular fracture of the lateral condyle of the right humerus with non-union of the fragment, which was displaced anteriorly (Fig. 4). On June 22, 1937, one of the authors (J. G. L.) explored the region of the right medial epicondyle, while the patient was under the influence of ether, administered by the open-drop method. A large neuroma of the ulnar nerve was discovered, posterior to the medial epicondyle. Neurolysis of the neuroma was done, and the release of tension caused the contents within the neural sheath to bulge between the edges of the incisions. The nerve was transplanted anteriorly in a muscle bed. The patient reported complete return of function of the hand and no residual symptoms, two years after the operation.

CASE 2. A housewife, thirty-eight years old, had been injured in a serious automobile accident. Among other injuries, she had suffered a fracture of the left olecranon process of the ulna, which had been treated by open reduction. When she was examined, five months after the accident, there had been no evidence of a peripheral-nerve lesion; roentgenograms had showed the fragments to be in excellent position; and the patient was attaining good return of elbow motion. However, three months later she had had limitation of motion of the elbow joint, and callus had obliterated the ulnar groove. Slight weakness of muscles supplied by the ulnar nerve had been noted, but no sensory impairment. It was thought advisable to transplant the ulnar nerve without delay, to avoid further destruction of nerve function. On August 14, 1934, one of the authors (J. G. L.) performed an anterior intramuscular transplantation of the ulnar nerve; the patient was given ether, administered by the open-drop method. The ulnar groove was found to be obliterated by callus and fibrous tissue, but a neuroma was not present. At the same operation the elbow joint was manipulated. Inquiry, twelve years after the operation, disclosed that the patient had obtained an excellent result, and had no residual symptoms.

CASE 3. A farmer, forty-five years old, had had a gonococcal type of arthritis of the right elbow, and for more than twenty years afterward had had pain and limitation of motion in that joint. Eight months before the patient's admission, numbness had developed in the ulnar half of the right hand; and four months later he had noticed wasting and weakness of the same hand. On examination, motor and sensory findings were typical of paralysis of the ulnar nerve. Roentgenograms of the elbow disclosed hypertrophic arthritis, with multiple loose osteocartilaginous bodies. On August 18, 1933, the medial aspect of the elbow joint was explored; the patient was given ether, administered by the open-drop method. The ulnar nerve was flattened, fibrotic, and under considerable tension, because of partial obliteration of the ulnar groove by the arthritic process. No neuroma was present. The nerve was elevated and then transplanted anteriorly into a muscle bed. Thirteen years later, the patient was working as a carpenter; he had no symptoms of paralysis of the ulnar nerve.

CASE 4. In a forty-year-old farmer, typical ulnar palsy developed insidiously on the right, over a period of about four years. About a year previous to the patient's admission, scalenotomy had been performed elsewhere, without benefit. The patient had habitually driven a tractor, resting one or the other of his elbows on a fender; this had subjected his elbow to repeated traumata. There was no history of other injuries to the elbow or of disease. Roentgenograms of the thorax and of the cervical portion of the spinal column showed no evidence of a cervical rib; and results of manoeuvres designed to demonstrate the scalenus anterior syndrome were negative. Both ulnar nerves were enlarged at the elbow; the right ulnar nerve was the larger.

Roentgenograms of the patient (Fig. 3-A) showed lateral displacement of the patella; the presence of a small loose body beside the lateral femoral condyle; and a depression in the condyle, corresponding to the size and position of this body. The roentgenographic diagnosis of dislocation of the patella was confirmed by physical examination, as well as at operation, and the case was classified as the congenital type.

The author's experience with the Goldthwait method of operation for recurrent dislocation of the patella had been so satisfactory in fourteen knees that this operation was done on each knee of this patient on August 4, 1936. However, as might have been determined if the operator had had more knowledge on the subject, the operation was of no value. On September 23, 1937, the right knee was operated upon according to the method of Conn, and the result was so satisfactory that the patient requested a similar operation on the left knee; this was done on November 19, 1937 (Fig. 3-B). The convalescence from each operation was uneventful, although slow as regards return of function and stability. At the end of one year the patient resumed her household duties, and six months later she returned to factory work. She had good stability, and no pain in either knee. A recent report (1946) is that the patient now has normal function in the knees, that there has been no recurrence of either pain or instability in the knee joints, and that she considers herself entirely well.

The operation suggested by Conn is logical in its development, and not too difficult in execution. The knee capsule is exposed by reflecting the skin flap. A longitudinal incision is made external to the patella, through the capsule and the synovial membrane. The tendinous attachments of the vastus lateralis and the vastus medialis of the quadriceps mass are freed from the quadriceps tendon itself. The patella is pushed into its normal position in the mid-line, which leaves a diamond-shaped gap in the line of the lateral incision. A piece of similar shape (which conforms to a piece of tinfoil placed over this gap) is then cut from the redundant capsule on the inner aspect of the joint, which includes the capsule and the synovial membrane. This piece is transferred to the gap on the lateral aspect and sutured in place with chromic catgut No. 1, care being taken to pass the sutures down to, but not through, the synovial membrane. The incision on the inner aspect of the joint is closed with similar sutures. The elongated fibers of the vastus medialis are shortened and sutured to the quadriceps and the upper border of the patella, the already shortened vastus lateralis is reattached to the quadriceps tendon, and the flaring quadriceps fibers are folded under the severed portion of the tendon. Weight-bearing is permitted in three weeks, and full use of the limbs is encouraged during the fourth week.

CONCLUSIONS

1. Congenital dislocation of the patella presents an entirely different operative problem than does the recurrent type of dislocation.
2. Extensive joint changes may occur as the condition progresses.
3. The operation of Conn for congenital dislocation of the patella offers a satisfactory prognosis.
4. The family history of a "knee condition" in four successive generations suggests an element of heredity on the maternal side.

NOTE: Since this article was written, roentgenograms have been obtained of the knees of the oldest aunt of this patient and of the youngest daughter of this aunt. These roentgenograms show definite dislocation of each knee.

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Neurological signs and symptoms of paralysis of the ulnar nerve were present only on the right side. One of the authors (J. G. L.), on August 31, 1944, explored the right ulnar nerve at the elbow and found a fusiform neuroma of the nerve in the ulnar groove. Neurolysis of the neuroma was performed, and the nerve was transplanted into a muscle bed anterior to the medial epicondyle of the humerus. Brachial-plexus regional anaesthesia was employed for this procedure. The patient's right hand improved steadily after the operation. About a year later, however, identical signs and symptoms developed in the left arm. On February 18, 1946, the same operative procedures were carried out on the left side. The patient obtained an excellent return of function in the right hand. He could not be located so that we might inquire as to return of function of the left hand.

Case 5. A fifty-year-old clergyman had had sensitivity of the right ulnar nerve since childhood. In his brother, who had a similar condition, atrophy and weakness of one hand had developed recently. After throwing a baseball or when resting on his elbow, the patient had always experienced tenderness in the region of the ulnar groove, and numbness and tingling in the hand. His symptoms always had been worse on the right. His occupation required incessant reading; he had habitually rested his right elbow on the arm of a chair. On examination, the ulnar grooves were found to be abnormally shallow bilaterally. The right ulnar nerve was enlarged and tender. There was motor paralysis of the muscles supplied by the ulnar nerve on the right side, but sensation was normal. On December 31, 1936, the medial aspect of the right elbow was explored, with the patient under the influence of regional anaesthesia of the brachial plexus. The ulnar groove was abnormally shallow on a developmental basis. The nerve was enlarged and fibrotic, but neuroma was not present. Ten years later, the patient reported that his only residual symptom was slight numbness of the ulnar side of the hand when he became fatigued from long, hard drives in his automobile. He was well satisfied with the results of the operation; no difficulty had developed on the left side.

Case 6. A farmer, seventy-one years old, had injured his right elbow at the age of twenty-five years. He had had a stiff elbow after the accident, but signs and symptoms of ulnar paralysis had not developed until ten months before his admission. Roentgenograms of the right elbow demonstrated extensive hypertrophic arthritis. At operation on May 7, 1930, the ulnar nerve was found to be firmly embedded in scar tissue behind the medial epicondyle. Anterior intramuscular transplantation of the nerve and neurolysis of the neuroma were performed. The patient regained normal function of the right hand, but three years later he returned with evidence of paralysis of the left ulnar nerve (Fig. 5, *a*). Roentgenograms showed moderate hypertrophic arthritis of the left elbow joint, with spur formation (Fig. 5, *b*). On August 29, 1933, a similar operative procedure was carried out on the left side; extensive adhesions and scar tissue were found to have accounted for the condition. The patient was re-examined two years after the last operation. At that time he had slight atrophy and weakness of the ulnar-supplied muscles on the left, but both arms had been restored to usefulness.

Case 7. Paralysis of the left ulnar nerve had developed in a restaurant owner, fifty-seven years old, over a two-year period prior to his admission. In addition to typical paralysis of this nerve, physical examination disclosed a palpable mobile mass in the left ulnar groove. Roentgenograms of the elbow demonstrated nothing abnormal. Clinically, the mass was thought to be a neuroma of the ulnar nerve. On November 27, 1945, surgical exploration of the region about the left elbow disclosed a multilocular ganglion cyst, about two centimeters in diameter, which arose from an adjacent tendon and was compressing the ulnar nerve. This cyst (Fig. 3) was completely removed; but transplantation of the nerve was not performed, since the elbow joint appeared to be normal otherwise. Six months later the patient reported satisfactory return of normal function in his left hand.

Case 8. An automobile mechanic, twenty-eight years old, suffered from progressive paralysis of the right ulnar nerve, which had followed an injury to his elbow. On physical examination he was found to have impairment of function of the ulnar nerve and a large, cystic, tender mass above the medial condyle on the right. Subcutaneous transplantation of the nerve had been performed elsewhere, but the patient had not obtained relief from pain and tenderness in the region of the elbow. His discomfort was severe enough to necessitate large doses of narcotic agents, and he was rapidly becoming addicted to them. Roentgenograms of the right elbow demonstrated nothing abnormal. Clinically, the mass was suspected of being a ganglion cyst. On August 13, 1943, surgical exploration of the ulnar nerve showed that the mass was a large fibrous neuroma of the ulnar nerve, measuring four by one by one centimeters (Figs. 2-A and 2-B). The neuroma was of such size that it was necessary to remove it and perform end-to-end anastomosis of the nerve in order to mobilize the nerve and transplant it into an intramuscular bed. Three years after the operation the patient was gainfully employed as an automobile mechanic, but he was dissaissfied with the result. He had residual paraesthesia and pain over the distribution of the ulnar nerve on the right, and a tender mass had recurred near the elbow.

DIAGNOSIS AND TREATMENT OF TARDY PARALYSIS OF THE ULNAR NERVE

Based on a Study of 100 Cases *

BY JAMES R. GAY, M.D., AND J. GRAFTON LOVE, M.D., ROCHESTER, MINNESOTA

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Tardy paralysis of the ulnar nerve is a chronic affection which is caused by a wide variety of pathological conditions in the region of the elbow joint. Its course is characterized by slow progression. Surgical intervention is the only satisfactory form of treatment. Since the ulnar nerve is superficial and, therefore, easily exposed to trauma at the elbow, any condition which alters the relationship of the components of the elbow joint is likely to stretch or to irritate the nerve. Transplantation of that part of the nerve anterior to the medial epicondyle into a muscle bed is the specific surgical procedure which has provided the best results. Serious consideration of all diseases and injuries of the elbow and prompt treatment of these conditions are the best means of preventing the occurrence of this type of paralysis.

One hundred patients with tardy ulnar-nerve paralysis, seen consecutively at the Mayo Clinic in the past twenty-five years, are the basis of this study. All except one of the patients were treated by surgical methods. This large group of patients provided statistically sound information in regard to the etiology, prophylaxis, diagnosis, and treatment of this disease. Ten cases will be reported here to illustrate the wide variety of etiological factors which cause tardy ulnar-nerve paralysis.

The first case of tardy ulnar-nerve paralysis in the literature was reported in 1878 by Panas, who presented a paper before *l'Académie de Médecine* in Paris. J. B. Murphy published the first American contribution in 1914. Davidson and Horwitz have published an excellent review of the literature.

Many authors have presented classifications of paralysis of the ulnar nerve, resulting from trauma, in which the nerve trunk remains intact. A combination of these classifications, which was found useful for the purpose of this study, is shown below:

A. Primary and secondary ulnar neuritis resulting from:
   1. Simple contusion;
   2. Recent fracture of the humerus, either of the medial epicondyle or in the supracondylar region;
   3. Recent dislocation of the elbow joint.

B. Tardy paralysis of the ulnar nerve, due to involvement of the elbow region by:
   1. Old fracture;
   2. Arthritis;
   3. Occupational trauma;
   4. Congenital anomalies;
   5. Old or recurrent dislocations;
   6. Tumors;
   7. Unknown factors.

ETIOLOGICAL ASPECTS

Most of the etiological information in the literature appears to be based on a relatively small number of cases. The authors have been impressed with ancient fractures of the elbow as exclusive causes of tardy paralysis of the ulnar nerve. In this study of 100 cases it was possible to make an analysis of the etiological factors involved, and to discover a wide range of circumstances which produce this condition.

* Read before the Harvey Cushing Society, Boston, Massachusetts, October 10, 1946.

CASE 9. A physician, twenty-eight years old, had suffered a fracture of the right elbow at fifteen years of age, which had been treated by the closed method of reduction. An increased carrying-angle type of deformity of the right elbow had developed on the basis of an ununited fracture of the lateral condyle of the humerus. Symptoms of a right ulnar-nerve palsy had commenced, five years later. The patient had undergone anterior subcutaneous transplantation of the ulnar nerve three times without success; these procedures had been done elsewhere. He also had received one extensive course of deep roentgen-ray therapy, elsewhere. The operations and the roentgen-ray therapy had provided only temporary relief from pain, and had not altered the progress of the atrophy and anaesthesia in his hand. His disability was of such severity that he was faced with the decision of giving up his chosen field of surgery or even of abandoning the practice of medicine. On May 11, 1938, the right ulnar nerve, which was found in subcutaneous tissues anterior to the medial epicondyle, was explored surgically. There was a fusiform enlargement of the nerve, six centimeters in length. Neurolysis of the neuroma was performed, and the nerve was transferred medially into a muscle bed. The patient was advised to continue his surgical training and to attempt surgical practice. Eight years later, this patient was a successful surgeon, who experienced only occasional slight numbness and tingling in his right hand after a strenuous working day.

CASE 10. A public accountant, sixty-three years old, was found, during an examination for unrelated conditions, to suffer from partial paralysis of the right ulnar nerve. There was no history of disease or injury of the elbow. However, the patient habitually rested his right elbow on a desk in his work as an accountant. He had complete motor paralysis of the ulnar nerve, and the right ulnar nerve was enlarged at the elbow. There was no evidence of sensory disturbance. Conservative treatment was advised. He was instructed to avoid resting his elbow in such a way as to injure the ulnar nerve, and a series of exercises were prescribed to maintain tone in the muscles supplied by this nerve. More than a year later the patient reported that his hand was functioning normally and that the atrophy was disappearing. Whereas he had not been able to button his clothes, shave himself, or write satisfactorily at the time he was examined, he could do all these things at the time he was dismissed.

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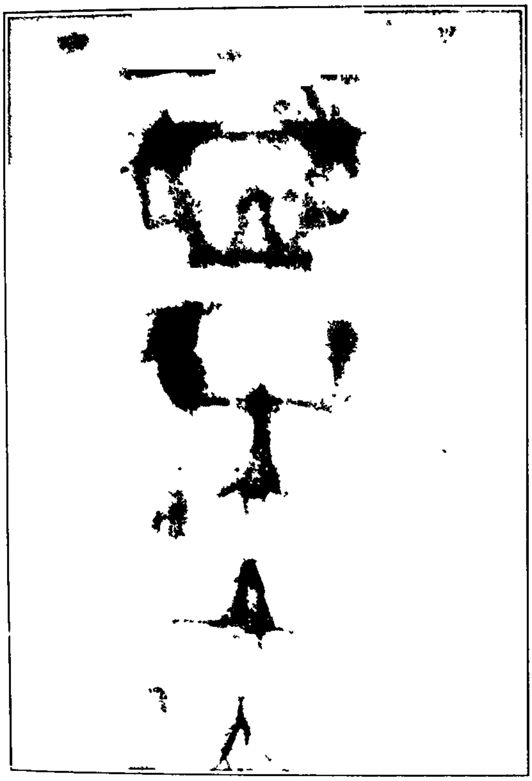

FIG. 3-E

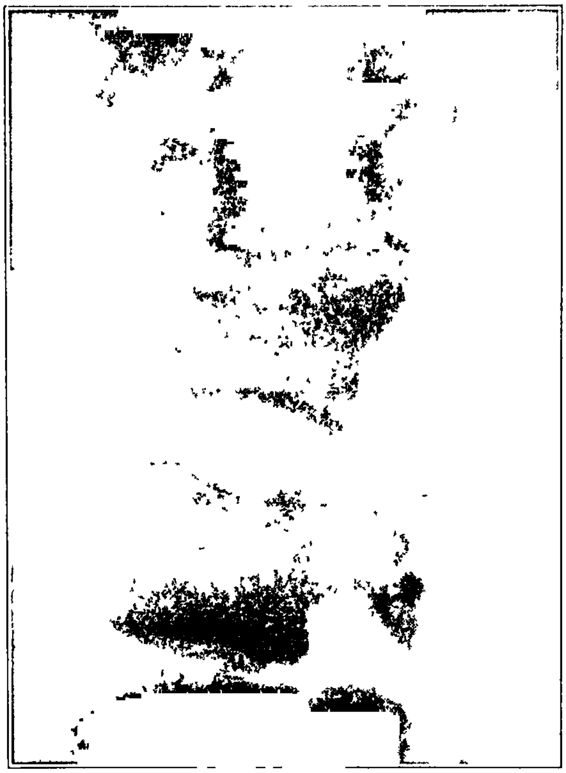

FIG. 3-F

Six months after reduction.

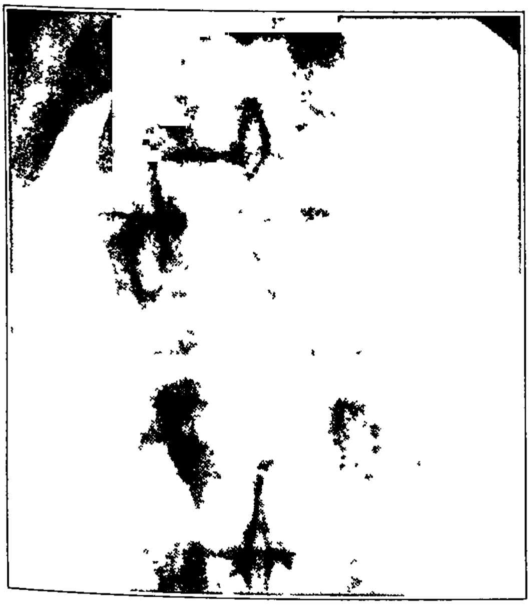

FIG. 3-G

FIG. 3-H

Present condition, five years after reduction; roentgenograms show redisplacement, but sound lateral and anterior fusion.

by hyperextension under a general anaesthetic. A recent review shows that the dislocation has recurred, without any recurrence of the paraplegia (Figs. 3-G and 3-H). Twelve patients are dead, but six are reported to have shown very slight signs of recovery. Of the other five still living, not one has shown any signs of recovery.

Of the two patients with partial paraplegia who were treated by open reduction, one has made a good degree of recovery, and, in spite of partial incontinence of urine, is doing light work. The other has made slight recovery, and is walking with a caliper brace.

Of the five patients with no paraplegia who were treated by open reduction, two have

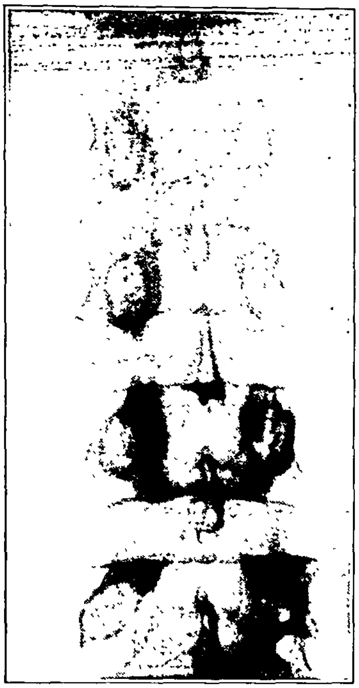

FIG. 4-A

FIG. 4-B

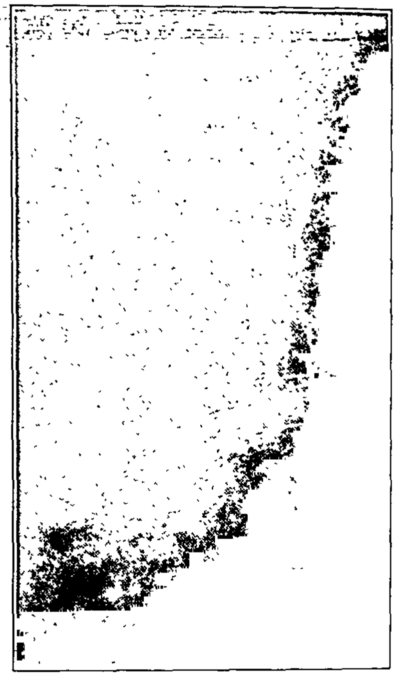

FIG. 4-C

Case 5, R. H. This patient had a fracture-dislocation between the twelfth thoracic and first lumbar vertebrae, with interlocking of the articular facets.
Figs. 4-A and 4-B: Before reduction.
Fig. 4-C: Immediately after reduction (only lateral view available).

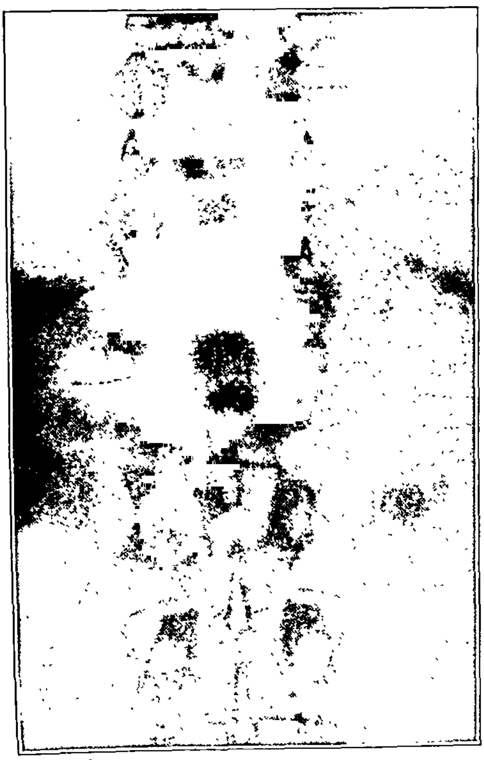

FIG. 4-D

FIG. 4-E

Present condition, six years after reduction; roentgenograms show complete redisplacement, but sound lateral fusion.

made a complete functional recovery from the skeletal lesion and are back at full work. The others showed good results, but are doing only light work.

No Reduction

Seven patients with complete paraplegia were not treated by reduction, open or closed, but simply by general nursing. Six of them showed no sign of recovery; but the most recent

FLOOR PAD FOR FOOT-EXERCISING

BY MAURICE H. HERZMARK, M.D., WASHINGTON, D. C.

Most cases of flat-foot or of weak foot can be prevented. Often the cause of flat-foot is a flat walking surface, and the condition can be prevented by an irregular surface. The arch of the human foot is supported by muscles, attached to the bones and ligaments. It has been developed, by a process of evolution, to adapt the foot to swift and easy movement over rough and irregular ground. The spring-like arch takes up the shock of the impact and reduces the surface of contact. Rough, pebbly ground, hot sandy soil, or cold, soggy marshland would be hard to negotiate on flat, splayed feet. In primitive times, when man hunted and was hunted, life depended upon well-developed nimble feet. His soil determined the kind of feet he would have. The rougher the ground, the better his feet Now, with well-paved sidewalks, polished floors, and smoothly rolled lawns, the feet that tread this smooth terrain do not develop spring and strength.

The infant who learns to walk on irregular and springy surfaces will build up the muscles of his feet and legs, which support the arches. By the time he has outgrown his play-pen days, his feet are strong; and walking habits have been developed which will keep his feet in the proper weight-bearing position.

FIG. 1

FIG. 2

Fig. 1: Note pronated feet, when child stands on flat surface.
Fig. 2: Child stands on a pad designed to exercise the feet (note knobs). Improved position of feet can be seen.

Current Literature

Osteotomy of the Long Bones. Henry Milch, M.D. Springfield, Illinois, Charles C. Thomas, 1947. $6.75.

If by philosophy is meant an attempt to think accurately about fundamental problems, then this volume by Henry Milch might well be titled, "The Philosophy of Osteotomy". Scarcely any topic in orthopaedic surgery is as hackneyed as osteotomy. It was one of the earliest orthopaedic operations. Hundreds of different methods have been devised and numerous articles have been published. To most of us it would seem that enough—possibly more than enough—had already been written, and yet in this book the author has given new points of view, has analyzed the accepted conventional procedures with refreshing originality, and thereby injected new life into what might otherwise have been a profitless field of orthopaedic thought.

The first part of the book is devoted to axial displacements which may occur in the long bones. These are divided into the lineal, torsional, transpositional, and angulational displacements. In his attempt to employ terms accurately, Milch rejects the accepted words "linear" and "longitudinal", and suggests "lineal" to describe the "axial displacement which occurs when an osteotomized fragment is moved either distally or proximally in the direction of its longitudinal axis". The term "torsional" is used rather than "rotational" to indicate an essential difference between the concept of *rotation,* which "connotes a change of the whole bone with respect to some external frame of reference", and *torsion,* which applies to a "change in the position of one part of the bone with respect to another part of the same bone". In discussing both the transpositional and angulational osteotomies, trigonometric formulae are used to substantiate the accuracy of the author's deductions.

The second part of the book deals chiefly with the "axial displacement of the femur which occurs in the coronal plane, and which has been called the abduction osteotomy". Here Milch's previous publications, describing the importance of the postosteotomy angle, are given due emphasis. His final chapter, "Resection of the Femoral Neck with Pelvic Support Osteotomy for Ankylosis of the Hip", is the logical outgrowth of a rich experience with the abduction osteotomy. Unquestionably, this operation will not find favor with the supporters of arthroplasty, but time alone can decide whether the Milch procedure may not eventually be considered the operation of choice when dealing with ankylosed arthritic hips.

Although Milch thinks essentially along mechanical lines, he is also alive to the biological implications of osteotomy. He shows a fine historical grasp and a thorough knowledge of the literature; yet he does not befog the issue with too many diverse opinions. Instead he seeks clarity by a vigorous expression of his own thinking.

It is only natural that such a book as this is not easy reading; many paragraphs have to be pondered like a problem in geometry. To the orthopaedic surgeon who is not afraid of intellectual exertion, however, this book will prove a stimulating guide and an incentive to more accurate orthopaedic surgery.

Surgery of the Hand. Ed. 2. R. M. Handfield-Jones, M.C., M.S., F.R.C.S. Edinburgh, E. and S. Livingstone Ltd., 20 shillings; Baltimore, The Williams and Wilkins Company, 1946. $5.50.

No attempt is made in Handfield-Jones's second edition of *Surgery of the Hand* to present the entire subject in great detail, but rather to give the essentials of primary hand care to the general surgeon, who must deal with the early problems of injury and infection.

The 164 pages are divided into three sections, covering infections, injuries, and other surgical lesions. Over half of the text deals with the subject of infection. The essentials of Kanavel's teaching, coupled with the author's vast experience, make this major section an especially valuable one. Handfield-Jones stresses primarily functional restoration of the infected hand, and turns his treatment at all times toward this key objective. Differential diagnosis of infection is carefully covered, and the care of the infected hand is outlined lucidly. The author emphasizes repeatedly the need for absolute certainty of diagnosis prior to any incision for drainage. The use of hot fomentations is discouraged in favor of dry heat.

The section on injuries covers the principles of Watson-Jones in the handling of fractures and dislocations. A chapter on burns gives the experience gained through the Royal Air Force.

Primary suture of severed flexor tendons within sheaths is condemned by the author, in accord with Iselin.

A statement is made that preservation of the proximal phalanx of the middle or ring finger, or a portion thereof, and not the metacarpal head, is necessary in preventing a rotation of the outer adjacent finger. Other authorities find that it is primarily the intact metacarpal head which prevents the deformity.

This carefully written volume will prove of great value to the surgeon in the care of primary hand injuries.

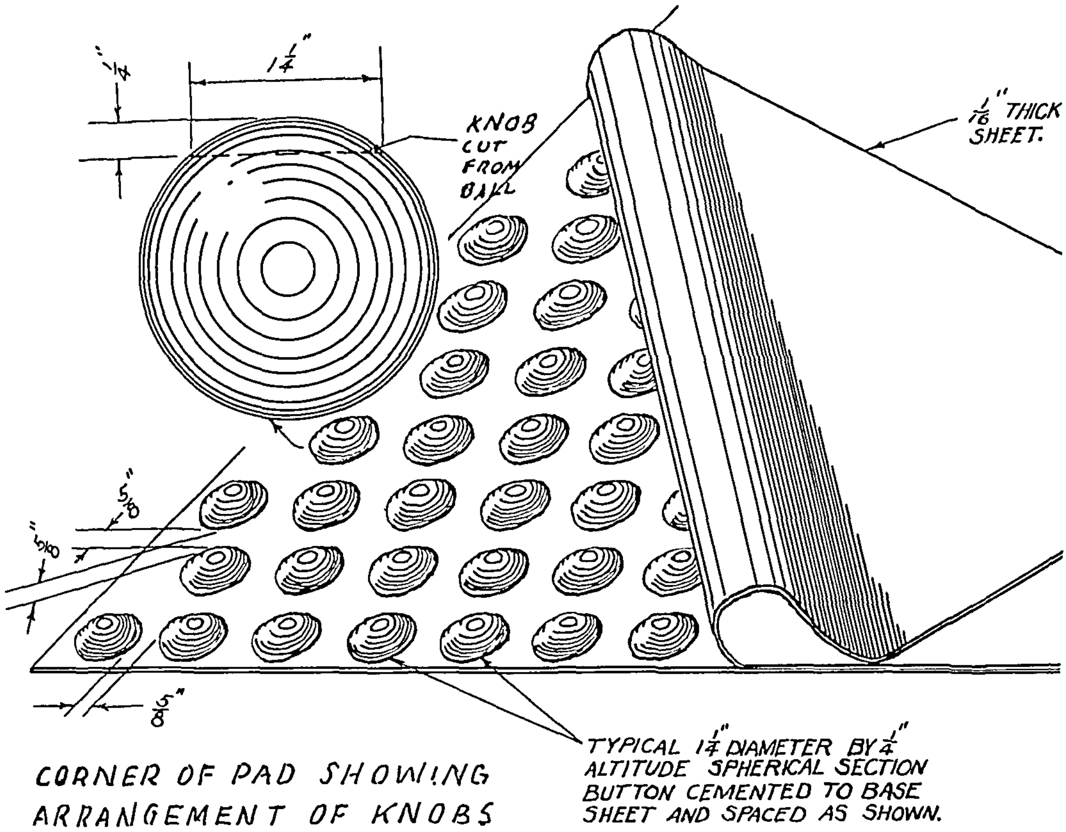

FIG. 3

Construction of rubber pad.

For a number of years it has been the author's practice to suggest that the play pen of a child learning to walk be fitted with a pad of irregular tufted material, so that the walking surface will rock the feet. The development of the feet in these children was such that none of them needed corrective shoes, arch supports, or other aids to proper weight-bearing.

Recently a very effective pad has been constructed from sponge-rubber sheeting, with segments of sponge-rubber balls cemented on (Fig. 3). Sheeting, one-sixteenth of an inch thick and forty by forty inches in size, to fit the floor of an ordinary play pen, was used. The balls were the type sold for the use of children. The segments were cut by outlining on the surface of a ball, having a diameter of two and one-half inches, as many circles one and one-quarter inches in diameter as possible. These segments were cut with a sharp straight knife, dipped in water. About eight segments with a flat bottom and curved top, one-quarter inch high, can be obtained from each ball. About 625 segments are cemented in staggered arrangement, with the curved surface against the sheet of sponge rubber. The pad is placed with the segments against the floor of the pen. This leaves the walking surface smooth in appearance, but the curved knobs under the pad rock the feet and prevent them from pronating or being used passively. This pad has the following advantages: It is soft and springy, yet has a smooth surface; it will not hurt the infant if he falls; it is sanitary; and the knobs are of the proper size and position to fit an infant's foot.

Experience over a period of fifteen years has shown that this method of automatically exercising the infant's feet will forestall flat or weak feet in later life.

Chirurgie der Infektionen. Mit Weitgehender Berücksichtigung der Behandlung. Prof. Dr. Rudolf Demel. Wien, Wilhelm Maudrich, 1947. $12.00.

This book on the surgery of infections is obviously written for the general surgeon. It is divided into two parts,—general and special. In the general section the problem of infections, anaesthesia, preoperative management, and general guiding principles of the treatment of infections are considered. In the special section the skull, head, spine and cord, neck, chest, abdomen, genitalia, and extremities receive separate treatment. However, of the 641 pages of the book, only ninety-four pages are assigned to the extremities. In a different part of the book, about ten pages cover the infections of the spine and cord and five pages deal with the management of the bones of the pelvis. There are 484 illustrations, some in color, which are well reproduced.

Throughout the text one encounters very few names familiar to the American reader. The book may be of interest to advanced medical students and to general surgeons who are familiar with the German language.

Health Insurance in the United States. Nathan Sinai, Dr. P.H., Odin W. Anderson, and Melvin L. Dollar. New York, The Commonwealth Fund, 1946. $1.50.

This short, factual monograph is another in the series published by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. Voluntary group health prepayment plans in this country are traced from their beginnings in 1915. The authors have been fair in pointing out the shortcomings as well as the benefits of such plans, and they paint an accurate picture of present needs.

In any discussion of a health insurance program—whatever form it may take—the proponents of the plan have one end in view: to provide for the public protection against the costs of illness and a satisfactory distribution of all existing facilities. This book offers no utopian solution, but it merely sets forth various problems of organization, whose solution will determine the future of voluntary health insurance.

Physical Medicine in General Practice. Edited by Arthur L. Watkins, M.D. Philadelphia, J. B. Lippincott Company, 1946. $5.00.

This book is part of the American Practitioner's Series. Much credit is due the Editor, Dr. Arthur L. Watkins; and Dr. George Morris Pierson has written a timely foreword.

The Editor has compiled the writings of fourteen well-known experts in the field of physical medicine. Physical therapy, rehabilitation, and occupational therapy are well presented, especially the first two. It is a pleasure to read the clinical presentation of the various subjects comprising *Physical Medicine in General Practice*. It is written in medical language which any practitioner can understand. The technical aspect is explained in terms easily comprehended. Emphasis is placed upon the clinical application, and many chapters contain new material.

The chapter on minor injuries deals with athletic traumata. These have not received enough attention in former books on physical medicine. Electrodiagnosis is presented in a comprehensive way, and peripheral-nerve lesions are discussed in the light of new and experimental work done during the war. The care of the acute and convalescent poliomyelitic patient is well explained on a rational basis. Rehabilitation and reconditioning in Army hospitals, as well as in civilian hospitals, are discussed in two chapters which every doctor should read.

It is a credit to the Editor that so much information and very complete references are contained in 332 pages; and the attractive appearance of the book and good paper are a credit to the publishers. The only criticism that can be raised is the scarcity of illustrations and the poor choice used in selecting some of them.

This is the first book published on physical medicine since World War II, and it is interesting to compare it with the books written after World War I. Such a comparison shows the development of physical medicine from a technical modality to an integral part of medicine, both therapeutic and diagnostic.

Although this book is intended for general practitioners, it can also be recommended to specialists and students of physical medicine.

Physikalische Medizin in Diagnostik und Therapie (Physical Medicine in Diagnosis and Treatment), 5 und 6 Auflage. Professor Dr. Med. Wolfgang Holzer. Wien, Wilhelm Maudrich, 1947. $9.00.

This book of 760 pages is one volume in a series on physical medicine, written by an eminently qualified Austrian physician. He was on the staff of the Physiology Department of the University of Vienna for many years, and his work has covered a variety of subjects. Since the author is a physician and an engineer, he is particularly qualified in physical medicine. In Europe, physical medicine includes electrocardiography, encephalography, roentgenotherapy, and radium therapy. In the United States, physical medicine excludes these subjects, but includes occupational therapy and rehabilitation.

Dr. Holzer has divided his subject into three divisions. In the first one, two chapters are devoted to physics and physiology. Here the author shows his training as an engineer. The various energies are treated

SLOTTED JAW FORCEPS FOR BONE-PLATING

BY S. PERRY ROGERS, M.D., EL PASO, TEXAS

The customary surgical technique in plating fractures of the long bones includes the use of bone-holding forceps, generally in pairs, to grasp both fragments and to manipulate them into reposition, after which one forceps is usually sufficient to maintain the reduction. The awkward stage of the procedure frequently has been the application of the plate. Often this has entailed loosening the forceps, losing the reduction, remanipulating the fragments, and juggling the forceps so as to get the plate beneath the forceps and properly placed across the reduced fracture. The alternate procedure has been to attach the plate to one unreduced fragment, and to hope that it will lie properly on the other fragment after reduction.

Fig. 1

Fig. 2

Provision of a slot of appropriate width and depth in the upper jaw of the holding forceps allows the introduction and attachment of the plate without disturbance of the reduction. In the instrument illustrated (Fig. 1), the upper (working) jaw faces the handles at an angle of 45 degrees, to facilitate access with minimum exposure. The grasping surfaces on each side of the slot are long enough to overlie a considerable amount of comminution, while the under jaw is sufficiently thin and narrow to allow its introduction with minimum stripping. A standard slip joint at the hub permits adjustment to any size of bone from a clavicle to a femur (Fig. 2). A standard locking device is incorporated in the handles.

clearly and correctly, based upon thorough technical knowledge and great experience as a research worker.

The second division is devoted to the application of physical medicine in diagnosis and research. This is excellently covered in five chapters. Electrocardiography, electro-encephalography, spirometers, and electrodiagnosis are discussed very extensively; and there is also a chapter on rest and exercise.

The third division, of twenty-one chapters, deals with the application of physical medicine in therapeutics. Each chapter follows a pattern, convenient for quick orientation. The subject is explained from the physical standpoint first. Many pertinent biological and physiological facts are reported next. Reference is then made to a variety of therapeutic and diagnostic methods and to apparatus for the evaluation of circulation, the nervous system, metabolism, et cetera. Such forms of treatment as balneology, hydrotherapy, electrotherapy, and mechanotherapy are described in detail. The construction of the commonly used devices is explained. Their therapeutic applications are reviewed critically as to indications and contra-indications, as shown in diagrams. The photographs and drawings, made by an excellent artist, are particularly well chosen and help to clarify the subject considerably. The weakest parts of the book are the chapters on therapeutic exercises; reconditioning and occupational therapy are neglected.

Despite the almost insurmountable difficulties prevailing today in Austria, the editor has done a splendid piece of work. Printing and paper are of the highest quality. As all previous editions were published under the Nazi regime, the author has completely neglected the Anglo-American literature. This should be corrected in a subsequent edition. The German literature, on the other hand, is referred to exhaustively in twenty-two pages of bibliography.

This book is recommended for those specialists and students who have a good command of the German language, as Holzer's style is a rather complicated one.

Surface and Radiological Anatomy for Students and General Practitioners. Ed. 2. A. B. Appleton, M.A., M.D. (Cantab.), W. J. Hamilton, M.D., D.Sc., F.R.S.E., and G. Simon, M.D., B.Ch., D.M.R.E. (Cantab.). Baltimore, The Williams and Wilkins Company, 1946. $7.00.

The authors of this book have presented a study of anatomy which, as the title suggests, goes beyond skeletal and postmortem examinations and, through the use of apparatus for special examinations and by the roentgenographic approach, helps to show how the living subject differs from the cadaver.

The illustrations, which are of excellent quality, include photographs of a member, as well as comparative drawings and roentgenograms, thereby showing the relationship between surface contours and deeper structures. Similarly, the text proceeds from surface examination to that of muscles, vessels, nerves, organs, and bones, including their relations to changing positions of the body. Individual variations in bodily type are emphasized.

The present edition has been rewritten and rearranged, and contains many new illustrations. The first section of the book deals with general anatomy and methods. The remainder is divided into six sections: the upper limb, the chest and back, the abdomen, the head and neck, the vertebral column, and the lower limb.

The presentation is clear, and the correlation of anatomy with clinical findings makes the book valuable.

Medical Addenda. Related Essays on Medicine and the Changing Order. Committee on Medicine and the Changing Order, New York Academy of Medicine. New York, The Commonwealth Fund, 1947. $1.75.

These essays supplement the series of volumes issued by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. In all, the Committee has published twelve volumes, and they form the foundation for the report of the Committee which summarizes the findings and points to a better future. As one of the Committee spokesmen points out: "The contents of these volumes are proof that the practice of medicine is changing from a private pursuit to a social obligation".

The essays in the present volume are able presentations of the most recent knowledge on such subjects as: Psychosomatic Medicine, Medical Social Work, Psychiatric Social Work, Chronic Diseases, and Rehabilitation and Convalescence. Of particular interest are the chapters on psychosomatic medicine and psychiatric social work. The psychiatrist, psychologist, and social worker are gradually coming to work as a trained, effective team; and, as time goes on, their combined efforts will be extremely beneficial, not only to the patient, but to our society as a whole.

Any one of the twelve monographs in this series is available through The Commonwealth Fund or the New York Academy of Medicine.

News Notes

The Fifteenth Annual Convention of **The American Academy of Orthopaedic Surgeons** will be held at the Palmer House, Chicago, January 24 through 29, 1948, under the presidency of Dr. Rex L. Diveley. A program of unusual interest has been prepared. Registration will begin Saturday morning, January 24. The Audio-Visual Program will be presented Saturday afternoon and Sunday morning, to be followed by the Instructional Courses on Sunday afternoon and Monday morning. The Scientific Program will begin on Monday afternoon and close at noon Thursday. Four distinguished foreign guests are expected to participate in the program. A preliminary program containing information concerning this meeting will be mailed to all members before the holidays.

Applications for Part I of the examination of **The American Board of Orthopaedic Surgery** must be received by the Secretary, Dr. Francis M. McKeever, 1136 West 6th Street, Los Angeles 14, California, *not later than* January 15, 1948.

The Annual Convention of **The National Society for Crippled Children and Adults, Inc.,** will be held at the LaSalle Hotel, Chicago, November 3 to 5, 1947. The program for Monday will be developed around the Convention theme "The Handicapped—a Great National Resource"; the Tuesday program will concern Rehabilitation; and the Wednesday program will be on Cerebral Palsy. All interested persons are cordially invited to attend the Convention.

The Annual Meeting of the **American Occupational Therapy Association** will be held at Hotel del Coronado, Coronado, California, November 2 to 7, 1947.

The American Academy of Allergy will hold its annual convention at Hotel Jefferson, St. Louis, Missouri, December 15 to 17, inclusive. All physicians interested in allergy problems are cordially invited to attend the sessions as guests of the Academy by registering, without payment of fee. The program and the scientific and technical exhibits have been arranged to cover a wide variety of conditions where allergic factors may be important. Advance copies of the program may be obtained by writing to the Chairman on Arrangements, Charles H. Eyermann, M.D., 634 North Grand Boulevard, St. Louis, Missouri.

The Annual Report of **The National Foundation for Infantile Paralysis** for the fiscal year ending May 31, 1947, has recently appeared. This report contains a valuable summary of the tremendous activities of the Foundation during this period, which was marked by severe epidemics of infantile paralysis.

The **Baruch Committee on Physical Medicine** has recently issued a report covering the period of April 1, 1945, to December 31, 1946. The report emphasizes the significant advance in physical medicine and rehabilitation during this period, and mentions in detail the work at various centers, which has been made possible by grants from the Research Fund.

Through **The John and Mary R. Markle Foundation,** scholarships are now being made available to young men and women, graduates of accredited medical schools in the United States and Canada, who contemplate careers of research and teaching in the sciences basic to medicine. The liberal "post-fellowship" grants are being made to candidates recommended by their medical schools.

Announcement has been made by the Mellon Institute of Pittsburgh of the establishment of research fellowships on orthopaedic appliances by the **Sarah Mellon Scaife Foundation.** The program of study will be carried out under the direction of the Department of Orthopaedic Surgery of the School of Medicine, University of Pittsburgh.

An interesting meeting of **German orthopaedic surgeons** was held at the *Universitätsklinik* in Heidelberg, on September 3, 4, and 5. The committee in charge of the congress included Prof. Weil of Heidelberg, Prof. Max Lange of Bad Tölz, and Prof. Hohmann of Munich.

At the opening session, Prof. Weil greeted the guests; Prof. Hohmann gave the introductory address;

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and Prof. Lange opened the scientific part of the congress, outlining the program which had been prepared.

The main topics discussed were:

The problem of providing for the care and rehabilitation of amputees.

The importance of the herniated nucleus pulposus as a cause of lumbago and sciatica.

New methods of treatment of bone and joint tuberculosis.

The operations for irreparable paralyses, following impairment of the peripheral nerves, resulting from accidental injuries; the indications for their use and the results which may be expected.

The treatment of flail joints after extensive joint resection.

Operative nailing of the hip joint in chronic disease.

There were several speakers on each of these general topics, with others presenting papers on related subjects, and general discussion following the formal presentation of papers.

The last two sessions featured a series of short presentations.

During the coming weeks, the **Committee on Postgraduate Training in Orthopaedic Surgery,** in association with the Council on Medical Education and Hospitals of the American Medical Association and The American Board of Orthopaedic Surgery, will conduct a survey of the orthopaedic-training services in the United States. Two hundred and forty-three hospitals will be visited by twenty-nine orthopaedic surgeons.

Information will be obtained from these hospitals on the clinical and basic-science training which the orthopaedic residents are receiving. There are at the present time approximately 550 doctors in training on approved orthopaedic residencies.

This survey will be completed by December 1, following which the reports will be reviewed by the Committee and recommendations made accordingly to the Board and Council.

A. R. Shands, Jr., M.D., Secretary

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The American Society for Surgery of the Hand will meet in Chicago on January 23 and 24, 1948, in conjunction with The American Academy of Orthopaedic Surgeons. Visitors are welcome to the scientific session. The preliminary program is as follows:

Volkmann's Ischaemic Contracture, Local in the Hand.
Sterling Bunnell, M.D., San Francisco, California.
Tendon Grafts as a Substitute for Flexor Tendons.
Sumner L. Koch, M.D., Chicago, Illinois.
Tendon Transfers and Arthrodeses in Combined Median and Ulnar Nerve Paralysis.
J. William Littler, M.D., New York, N. Y.
Initial Treatment of Hand Injuries: Some Common Errors.
Condict W. Cutler, M.D., New York, N. Y.
Transplantation of Metatarsals to the Hand to Replace the Metacarpal.
Walter C. Graham, M.D., Santa Barbara, California;
Captain Daniel Riordan, M.C., Phoenixville, Pennsylvania (by invitation).
Metacarpal Transfer for Improving the Function of the Crippled Hand.
Lt. Colonel Gilbert L. Hyroop, M.C., Battle Creek, Michigan.
Tenosynovitis of the Extensor Carpi Ulnaris Tendon Sheath.
Clarence A. Luckey, M.D., Oakland, California.
Experimental Study of Cellophane in Prevention of Adhesions after Tendon Suture.
William H. Requarth, M.D., Chicago, Illinois.
Z-Plasty *versus* Free Skin Graft for Correction of Volar Skin Contractures of the Hand.
William H. Frackelton, M.D., Milwaukee, Wisconsin.
Tumors of the Hand.
Michael L. Mason, M.D., Chicago, Illinois.
Mobilization of Stiff Finger Joints.
S. Benjamin Fowler, M.D., Nashville, Tennessee.
Report of the Committee on Rehabilitation.
Donald B. Slocum, M.D., Eugene, Oregon.
Opponens Transplant.
John W. Kirklin, M.D., Rochester, Minnesota (by invitation).
Sympathetic Surgery for Lesions of the Upper Extremity.
C. Hunter Sheldon, M.D., Pasadena, California (by invitation).

Presentation of Cases.
Sumner L. Koch, M.D., Chicago, Illinois;
Michael L. Mason, M.D., Chicago, Illinois;
Harvey S. Allen, M.D., Chicago, Illinois.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixtieth Annual Meeting of The American Orthopaedic Association, under the presidency of Dr. LeRoy C. Abbott, was held at The Homestead, Hot Springs, Virginia, June 27, 28, 29, and 30, 1947. An excellent program had been prepared by the Program Committee and the standard of the papers from both guests and members was unusually high.

The program follows:

FRIDAY, JUNE 27

Morning Session

The Primary Suturing of Compound Fractures Including Immediate Internal Fixation, Skin Graft, and Compression Dressings.
Arthur G. Davis, M.D., Erie, Pennsylvania.
Discussion: H. Earle Conwell, M.D., Birmingham, Alabama;
Kellogg Speed, M.D., Chicago, Illinois.

The Management of Venous Thrombosis of the Extremities.
Daniel C. Elkin, M.D., Emory University, Georgia (by invitation).

Follow-up Report on a New Surgical Procedure for Lymphoedema of the Extremities.
H. B. Macey, M.D., Temple, Texas.
Discussion: Ralph K. Ghormley, M.D., Rochester, Minnesota;
Daniel C. Elkin, M.D., Emory University, Georgia (by invitation).

Bone Marrow and Blood Studies in Multiple Myeloma and Certain Other Skeletal Lesions.
Ernest H. Falconer, M.D., San Francisco, California (by invitation).

Bone and Joint Changes in Hemophilia.
Ralph K. Ghormley, M.D., Rochester, Minnesota;
Reed S. Clegg, M.D., Rochester, Minnesota (by invitation).
Discussion: William T. Green, M.D., Boston, Massachusetts;
Guy A. Caldwell, M.D., New Orleans, Louisiana.

Internal Fixation for Lumbosacral Fusion.
Donald King, M.D., San Francisco, California.
Discussion: Lenox D. Baker, M.D., Durham, North Carolina;
Alan DeForest Smith, M.D., New York, N. Y.

Operation to Correct the Valgus Deformity Resulting from Pott's Fracture.
E. B. Mumford, M.D., Indianapolis, Indiana.
Discussion: Frederick C. Kidner, M.D., Detroit, Michigan;
H. Earle Conwell, M.D., Birmingham, Alabama.

Afternoon Session

The Painful Shoulder—Observations on the Role of the Tendon of the Long Head of the Biceps Brachii in its Causation.
Harold H. Hitchcock, M.D., Oakland, California;
Charles O. Bechtol, M.D., Oakland, California (by invitation).
Discussion: J. Albert Key, M.D., St. Louis, Missouri;
Robert W. Johnson, M.D., Baltimore, Maryland.

A Preliminary Report on the Evaluation of Modifications of the Bankart Procedure for Recurrent Dislocations of the Shoulder Joint.
Joseph B. Josephson, M.D., San Jose, California (by invitation);
Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania.
Discussion: Frederic C. Bost, M.D., San Francisco, California;
Toufick Nicola, M.D., Montclair, New Jersey.

Extraskeletal Ossifications Simulating Sarcoma.
Howard Hatcher, M.D., Chicago, Illinois.
Discussion: Allen F. Voshell, M.D., Baltimore, Maryland;
Samuel Kleinberg, M.D., New York, N. Y.;
Dallas B. Phemister, M.D., Chicago, Illinois.

New Method for Fusion of Ununited Fractures of the Carpal Bones.
Paul B. Steele, M.D., Pittsburgh, Pennsylvania.

Discussion: Edwin F. Cave, M.D., Boston, Massachusetts;
Arthur B. LeMesurier, M.B., Toronto, Ontario, Canada.

The Cineplastic Method in Upper-Extremity Amputations.
Rufus H. Alldredge, M.D., New Orleans, Louisiana.
Discussion: Paul B. Magnuson, M.D., Chicago, Illinois;
Philip D. Wilson, M.D., New York, N. Y.;
Verne T. Inman, M.D., San Francisco, California.

Pseudarthrosis in the Lumbosacral Spine.
Mather Cleveland, M.D., New York, N. Y.;
David M. Bosworth, M.D., New York, N. Y.;
Frederick R. Thompson, M.D., New York, N. Y. (by invitation).
Discussion: Joseph S. Barr, M.D., Boston, Massachusetts;
Eugene M. Regen, M.D., Nashville, Tennessee;
Alan DeForest Smith, M.D., New York, N. Y.

SATURDAY, JUNE 28

Morning Session

The Management of Comminuted Fractures of the Distal End of the Humerus Involving the Elbow Joint.
John L. McDonald, M.D., Toronto, Ontario, Canada.
Discussion: Walter P. Blount, M.D., Milwaukee, Wisconsin;
Walter G. Stuck, M.D., San Antonio, Texas.

Fractures of the Capitellum Humeri.
John C. Wilson, M.D., Los Angeles, California.
Discussion: Edwin W. Ryerson, M.D., Chicago, Illinois;
T. Campbell Thompson, M.D., New York, N. Y.;
J. S. Speed, M.D., Memphis, Tennessee.

Homografts in Orthopaedic Surgery.
Myron O. Henry, M.D., Minneapolis, Minnesota.
Discussion: Rufus H. Alldredge, M.D., New Orleans, Louisiana;
J. S. Speed, M.D., Memphis, Tennessee;
Alberto Inclan, M.D., Havana, Cuba;
Alan DeForest Smith, M.D., New York, N. Y.

Cartilaginous Cup Arthroplasty in Ununited Fractures of the Neck of the Femur.
John R. Moore, M.D., Philadelphia, Pennsylvania.
Discussion: Joseph A. Freiberg, M.D., Cincinnati, Ohio;
Paul C. Colonna, M.D., Philadelphia, Pennsylvania.

Surgical Treatment of Intractable Plantar Warts.
James A. Dickson, M.D., Cleveland, Ohio.
Discussion: R. Plato Schwartz, M.D., Rochester, N. Y.;
James E. M. Thomson, M.D., Lincoln, Nebraska;
A. W. Farmer, M.D., Toronto, Ontario, Canada.

An Evaluation of Penicillin Therapy in Acute Hematogenous Osteomyelitis.
W. A. Altemeier, M.D., Cincinnati, Ohio (by invitation).

Acute Hematogenous Osteomyelitis. A Study on Treatment.
I. William Nachlas, M.D., Baltimore, Maryland;
Herbert R. Markheim, M.D., Baltimore, Maryland (by invitation).
Discussion: Dallas B. Phemister, M.D., Chicago, Illinois;
Frank D. Dickson, M.D., Kansas City, Missouri;
A. W. Farmer, M.D., Toronto, Ontario, Canada.

SUNDAY, JUNE 29

Morning Session

Certain Features of the Mechanics of the Hip Joint.
Verne T. Inman, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.B., San Francisco, California (by invitation).

Congenital Pseudarthrosis—Follow-up Study after Massive Bone-Grafting.
Harold B. Boyd, M.D., Memphis, Tennessee;
Kermit W. Fox, M.D., Memphis, Tennessee (by invitation).
Discussion: Halford Hallock, M.D., New York, N. Y.;
Rex Diveley, M.D., Kansas City, Missouri.

Muscular Torticollis.
Fremont A. Chandler, M.D., Chicago, Illinois.
Discussion: J. Hiram Kite, M.D., Atlanta, Georgia;
Robert V. Funsten, M.D., Charlottesville, Virginia.
The Nitrogen Content of Bone. A Laboratory Study.
L. J. Strabino, M.D., Wilmington, Delaware (by invitation);
L. E. Farr, M.D., Wilmington, Delaware (by invitation);
A. R. Shands, Jr., M.D., Wilmington, Delaware.
Discussion: Carl E. Badgley, M.D., Ann Arbor, Michigan;
William T. Green, M.D., Boston, Massachusetts.
Presidential Address.
LeRoy C. Abbott, M.D., San Francisco, California.
Experimental Intervertebral-Disc Lesions.
J. Albert Key, M.D., St. Louis, Missouri;
Lee T. Ford, M.D., St. Louis, Missouri (by invitation).
Discussion: Edward L. Compere, M.D., Chicago, Illinois;
Joseph S. Barr, M.D., Boston, Massachusetts.
Overlap Bone Operation for Serious Malunions and Persistent Non-Unions of Fractures of Both Bones of the Forearm.
J. Warren White, M.D., Greenville, South Carolina.
Discussion: Robert D. Schrock, M.D., Omaha, Nebraska;
Robert W. Johnson, M.D., Baltimore, Maryland.

MONDAY, JUNE 30

Morning Session

Symposium on Congenital Dislocation of the Hip.
Alan DeForest Smith, M.D., New York, N. Y., *Chairman.*
Embryology of the Hip with Etiology and Pathology of Congenital Dislocation.
Carl E. Badgley, M.D., Ann Arbor, Michigan.
Results of Treatment of Congenital Dislocation of the Hip in Infancy.
Frederic C. Bost, M.D., San Francisco, California;
Helen Hagey, M.D., San Francisco, California (by invitation);
Edwin R. Schottstaedt, M.D., San Francisco, California (by invitation).
Results of Treatment of Posterior Congenital Dislocation of the Hip.
C. H. Crego, Jr., M.D., St. Louis, Missouri.
J. R. Schwartzmann, M.D., St. Louis, Missouri (by invitation).
Results of Treatment of Congenital Dislocation of the Hip.
Wallace H. Cole, M.D., St. Paul, Minnesota.
Late End-Result Studies of Treatment of Congenital Dislocation of the Hip.
A. Bruce Gill, M.D., Philadelphia, Pennsylvania.
Follow-up Studies and Additional Observations in Primary Anterior Congenital Dislocation of the Hip.
H. R. McCarroll, M.D., St. Louis, Missouri.
Congenital Dislocation of the Hip with Treatment in Older Age Group.
H. R. McCarroll, M.D., St. Louis, Missouri.
Report of Results of Treatment of Congenital Dislocation of the Hip by Osteotomy.
Herman C. Schumm, M.D., Milwaukee, Wisconsin.
Report of Results of Treatment of Irreducible Congenital Dislocation of the Hip by Arthrodesis.
Charles J. Frankel, M.D., Charlottesville, Virginia (by invitation).
Report of Results of Treatment of Congenital Dislocation of the Hip by Vitallium-Mold Arthroplasty.
M. N. Smith-Petersen, M.D., Boston, Massachusetts.
Discussion: George K. Coonse, M.D., Boston, Massachusetts;
Leo S. Lucas, M.D., Portland, Oregon;
Charles O. Bechtol, M.D., Oakland, California (by invitation);
Beckett Howorth, M.D., New York, N. Y.;
Edward L. Compere, M.D., Chicago, Illinois;
Carl E. Badgley, M.D., Ann Arbor, Michigan;
Joseph A. Freiberg, M.D., Cincinnati, Ohio.

Executive Sessions were held at noon on Saturday, June 28, and Monday, June 30. The Annual Association Banquet was given on Saturday evening, June 28.

Robert I. Harris, M.B., Toronto, Ontario, Canada, is President of The Association for the year 194
1948.

At the last Executive Session, the following officers, members of committees, and delegates were electe

Officers

President-Elect: Ralph K. Ghormley, M.D., Rochester, Minnesota;
Vice-President: Alberto Inclan, M.D., Havana, Cuba;
Secretary: C. Leslie Mitchell, M.D., Detroit, Michigan;
Treasurer: Frank D. Dickson, M.D., Kansas City, Missouri.

Committee Members

Membership Committee: Wallace H. Cole, M.D., St. Paul, Minnesota;
Program Committee: Joseph A. Freiberg, M.D., Cincinnati, Ohio;
Research Committee: I. William Nachlas, M.D., Baltimore, Maryland.

Delegate to the American College of Surgeons: Kellogg Speed, M.D., Chicago, Illinois.

Representatives on The American Board of Orthopaedic Surgery:

H. Earle Conwell, M.D., Birmingham, Alabama;
Arthur G. Davis, M.D., Erie, Pennsylvania.

The following were elected to active membership in The Association:

George Carpenter, M.D., Nashville, Tennessee;
Verne T. Inman, M.D., San Francisco, California;
R. B. Raney, M.D., Durham, North Carolina;
Clay Ray Murray, M.D., New York, N. Y. (posthumously).

ACKNOWLEDGMENTS

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The Bulletin of the U. S. Army Medical Department (Washington, D. C.), **7:** Nos. 4 to 9, 1947.
Endogeneous Endocrinotherapy Including the Causal Cure of Cancer. Compendium by Dr. Jules Samuels. Amsterdam, Holdert and Co., 1947.
Evaporated Milk Association (Chicago, Illinois), "Infant Feeding with Evaporated Milk".
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Médica (Matanzas, Cuba), **6:** Núms. 3 y 4, 1947.
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The Physiotherapy Review (New York, N. Y.), **27:** No. 4, 1947.
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Sanidad y Beneficencia Municipal (Habana, Cuba), **6:** Núm. 1, 1946; **7:** Núm. 1, 1947.
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CLAY RAY MURRAY
1890–1947

In June of this year, Clay Ray Murray was elected posthumously to The American Orthopaedic Association. There could have been no more suitable and appropriate expression of the respect and affection in which he was held by orthopaedic surgeons.

He died on June 14, 1947.

Native of New York City, he was graduated from the College of Physicians and Surgeons in 1912. There followed four years of internship at the New York Hospital and several years of service abroad in the Army Medical Corps. In 1921 he joined the Surgical Staff of the New York Hospital, and later that of the Lincoln Hospital. At the time of its establishment in 1928, he was appointed Assistant Director of the Fracture Service of the Presbyterian Hospital and Associate Professor of Surgery at the College of Physicians and Surgeons. He became Chief of the Fracture Service and Professor of Orthopaedic Surgery in 1945.

Although his dominant surgical interest and the greater part of his life work were devoted to fractures, he became a thoroughgoing student of orthopaedic surgery. In the broader field, clinical experience, wide reading, and extensive travels, which made possible adequate visits at many of the leading clinics of the world, gave him an unusually rich background and high potential. He was very much interested in *The Journal.* One of his last professional duties was to serve as a representative of The American Academy of Orthopaedic Surgeons at the conference held in London, May 27, 1947, to formulate recommendations for the organization of British-American co-publication of *The Journal.*

His original contributions, including work on the healing process in bone following fracture, studies of the reaction of bone to various high-alloy metals, and developments in the technique of operative treatment of fractures, are valuable.

His intensity and enthusiasm kindled in his students a like flame; as a teacher he was successful. His hard-won convictions and graphic style made him a forceful speaker and writer.

Plagued by illness which seldom left him free of physical handicap, from the time of his internship, he never complained, he was never irritable. Instead, he retained an inexhaustible enthusiasm for orthopaedic surgery and an extraordinary capacity for accomplishment. Loyal, esteemed, mature in skill and judgment, a seemingly tireless worker, he will remain fixed in our memories even more for his deep and unfailing enthusiasm and his sheer courage.

BARNEY JAMES HEIN
1889–1947

Word has been received of the death of Barney J. Hein, on August 17, after a brief illness. Dr. Hein was born in Toledo, Ohio, and, except for three years of postgraduate work at Harvard Medical School and for service overseas in World War I, as Captain in the Army Medical Corps, he spent his life in Toledo. He received his medical degree from Toledo Medical College in 1912 and then served his internship at St. Vincent's Hospital.

He devoted a good deal of his time to industrial surgery, served on the staffs of the Flower Hospital, Mercy Hospital, Toledo Hospital, and Women's and Children's Hospital, and was Chief of the Orthopaedic Staff at St. Vincent's Hospital. He was also a member of a number of societies, including the American Medical Association and the Ohio State Medical Association, and was a fellow of the American College of Surgeons and The American Academy of Orthopaedic Surgeons.

In addition to his accomplishments in the field of orthopaedic surgery, Dr. Hein was active in Toledo civic organizations. He will be greatly missed by his associates and friends.

Y

SUBJECT INDEX

A

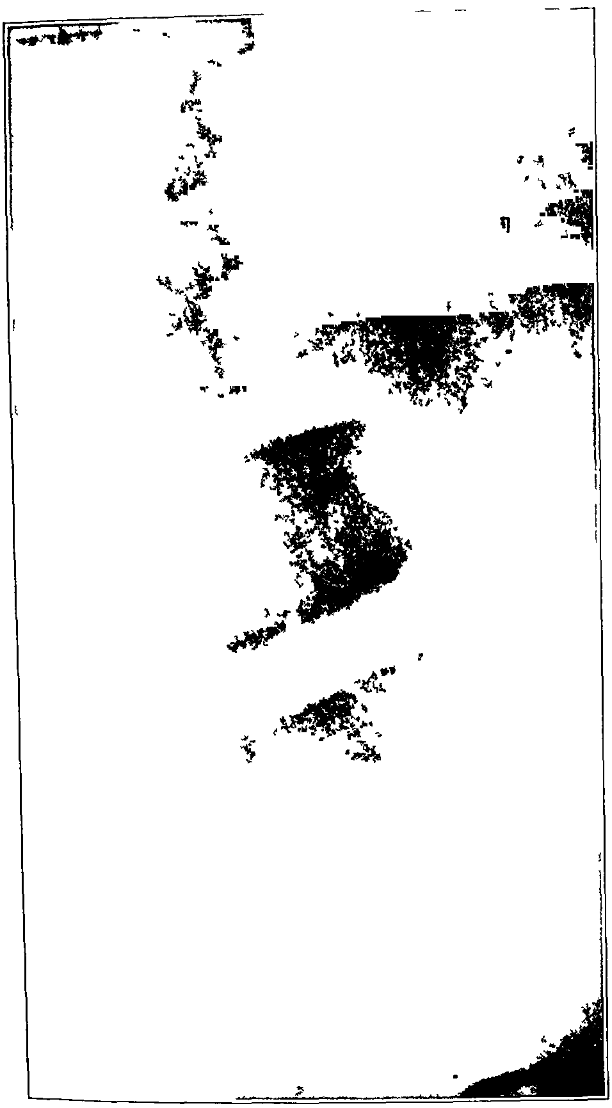

FIG 5-A

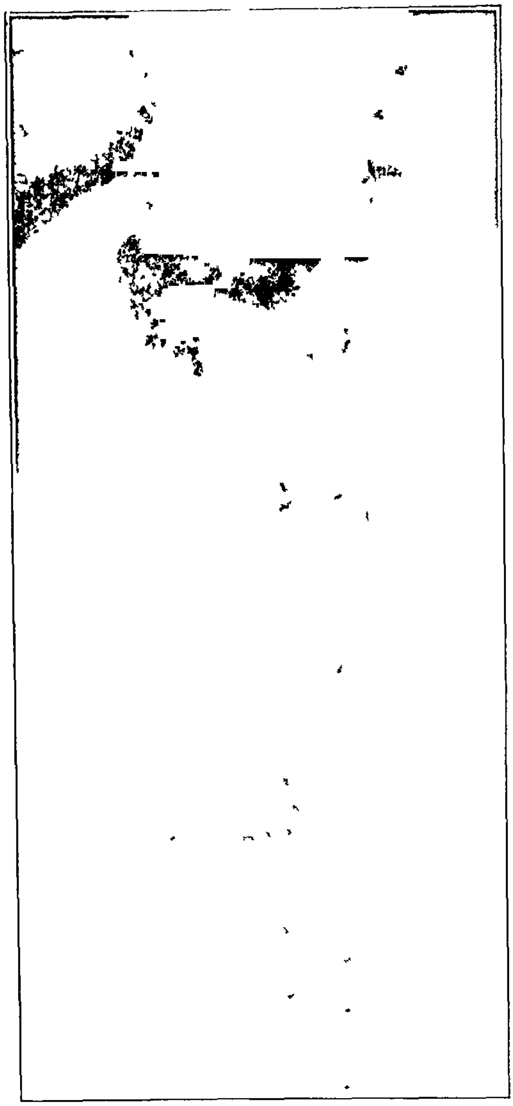

FIG. 5-B

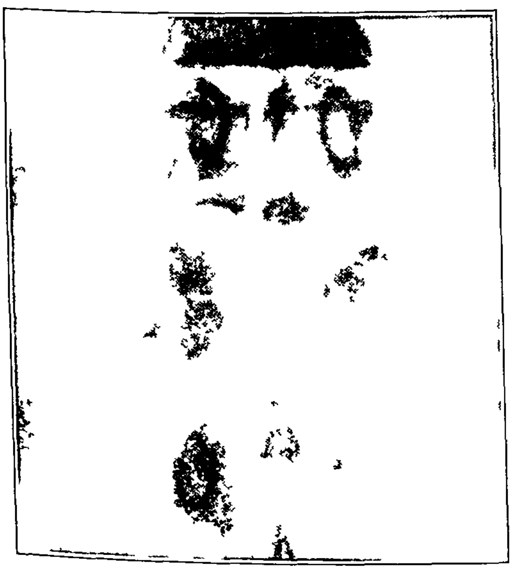

FIG 5-C

FIG 5-D

Case 6, E F This patient had a fracture-dislocation between the eleventh and twelfth thoracic vertebrae, with interlocking of the articular facets Figs 5-A and 5-B Condition on admission. Figs 5-C and 5-D Present condition, ten months later. These films show that no reduction has occurred, yet this patient's paraplegia shows signs that a complete recovery may be e

TABLE III

RESULTS

Degree of Paraplegia	No. of Cases	Method of Reduction		
		Closed	Open	No Reduction
Complete	30	5 (1 Hyperextension)	18	7
Partial	3	1	2	0
None	10	4 (4 Hyperextension, 1 Successful)	5	1
Totals	43	10	25	8

one will probably make a complete, or almost complete, recovery. This patient sustained a fracture-dislocation between the eleventh and twelfth thoracic vertebrae, with interlocking of the articular processes and a complete paraplegia. He was very ill on admission, and for this reason it was not thought worth while to attempt reduction. Six weeks after the injury, however, signs of motor recovery in both lower limbs were noted, followed by some control of the sphincters after three months. He was walking within three months of his injury; now, ten months later, he is at a Rehabilitation Center, and it is anticipated that he will make an almost complete functional recovery. This case would seem to indicate that the possibility of recovery in a complete paraplegia does not depend upon the reduction, whether open or closed, but upon the initial degree of injury to the spinal cord. This is still presumably stretched and attenuated, yet recovery is occurring (Figs. 5-A, 5-B, 5-C, and 5-D).

Signs of Recovery

The estimation of signs of neurological recovery in completely paraplegic patients is always a matter of great difficulty in the early stages. Unless approached in a very critical fashion, fallacious signs of recovery may be recorded. Patients will, for instance, move the foot by dragging and pushing a paraplegic limb, if the heel is not supported clear of the mattress. The patient is always anxious to please, and, unless questioned carefully, will admit sensation which is not really felt.

The earliest signs of recovery have been recorded as occurring immediately after reduction in some instances; in others, as late as three months after reduction. Sensation seems to be recovered earlier than muscle power. *The early appearance of recovery seems to be no indication of the eventual prognosis*; in the patients showing almost complete recovery, the first signs were noted as early as four hours after reduction or as late as six weeks.

Although treated by immobilization in plaster for a period of about four to six months, several of those patients in whom complete reduction has been performed have, in the recent survey, been found to have redislocations (Figs. 3-A to 3-F and 4-A to 4-E).

Redisplacement does not necessarily mean a painful back, however. Indeed, this has been followed in all instances by spontaneous bony fusion between the two affected vertebrae, and the functional result has been excellent. Furthermore, there has been no evidence that redislocation has been followed by further signs of nerve damage.

Complications

In two cases, a most interesting complication was observed. This consisted of an extensive myositis ossificans in the pelvifemoral muscles around both hip joints (Figs. 6 and 7). This was noted in both instances about six months after the accident. The masseuse treating both patients noticed an increasing resistance to passive movements at the

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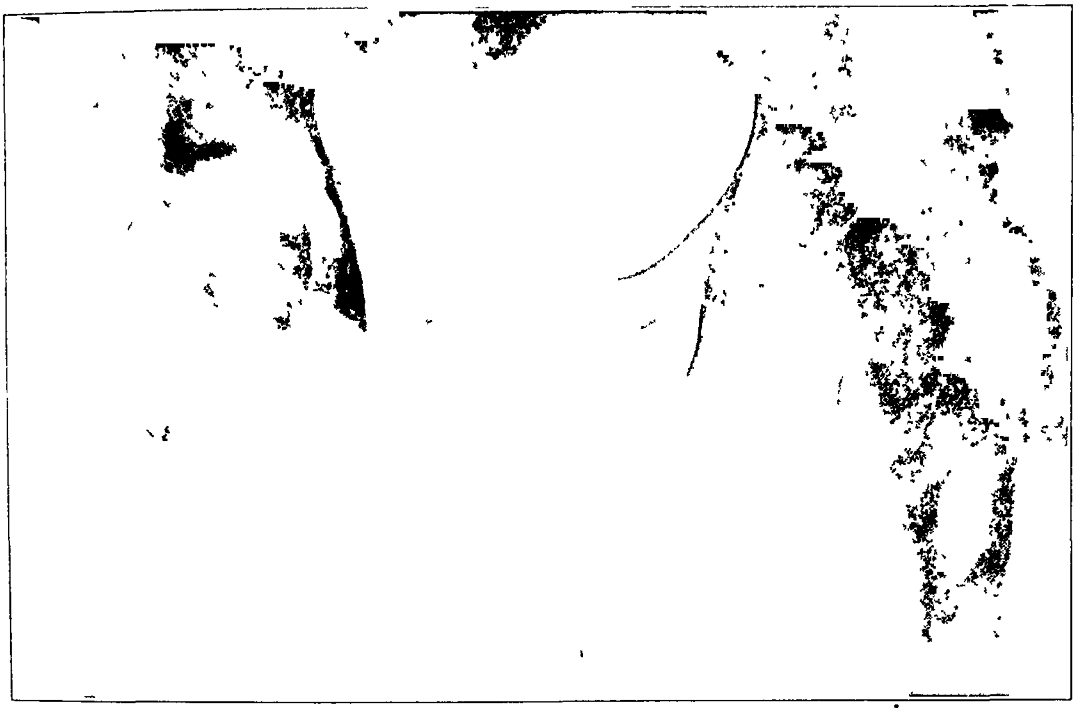

FIG. 6

Case 7, J. W. This is a case of fracture-dislocation between the eleventh and twelfth thoracic vertebrae, with complete paraplegia; the patient did not recover. This film shows extensive myositis ossificans around both hip joints.

FIG. 7

Case 8, R. S. This is a case of fracture-dislocation between the first and second lumbar vertebrae, with complete paraplegia; the patient did not recover. The film shows extensive myositis ossificans around both hip joints.

hips, commencing about the fourth month. In one case, there was no evidence of a similar condition elsewhere in the body; in the other, there was an abnormal ossification in the region of the knee joint, and a large stone subsequently developed in the patient's kidney. In both instances, the urea excretion was poor; but no abnormality in the blood calcium, phosphorus, or phosphatase was noted. It has been suggested that this myositis ossificans may be due to one or both of the following factors:

1. The impaired urinary excretion of nitrogenous bodies, causing a mobilization of calcium from the bones of the paralytic limbs. The normal blood chemistry is against this, although it must be added that experiments to determine calcium and phosphorus balance were impossible because of wartime conditions.

2. A Charcot-like reaction around a denervated joint, subjected to the repeated minor traumata of passive stretching by the masseuse.

CONCLUSIONS

1. The site of the lesion determines, to some extent, the possibility and the degree of paraplegia. There is a higher relative incidence of paraplegia at the thoracolumbar junction than in the lower lumbar region. This presumably is due to (a) the larger size of the neural canal, and (b) the toughness of the cauda equina, as compared with the spinal medulla.

2. The extent of skeletal damage is no indication of the degree of cord trauma. For instance, in the thoracolumbar region, a simple interlocking of the articular facets, with a minimum anteroposterior shift, is often associated with complete paraplegia; yet at this site complete displacement must indicate complete transection of the cord. In the lower lumbar region, however, gross displacement may be present without paraplegia.

3. The method of reduction seems to play little or no part in the possibility of recovery. In the small series under discussion, closed reduction seemed to give better results than open, but it would appear to be doubtful whether reduction matters at all.

4. The prognosis, if reasonable care is taken not to inflict further damage on the cord by careless handling, is surely decided at the time of the initial trauma.

5. The idea is disproved that stretching or attenuation of the cord may be an important cause in preventing recovery from paraplegia in cases of fracture-dislocation with interlocking facets.

6. The early appearance of the first signs of recovery of sensation or of motor power is no indication of the eventual prognosis.

7. Hyperextension, particularly with anaesthesia, which produces complete muscle relaxation, is to be condemned. In the present series, however, it has been tried in error on several occasions *without anaesthesia,* without disaster; and in one case it resulted in reducing the fracture-dislocation.

8. In the series examined, the dislocation, if reduced, has very often recurred, but without further signs of cord injury. Furthermore, this redisplacement is commonly associated with spontaneous anterior or lateral fusion of the vertebral bodies, giving rise to an excellent skeletal function.

One has not the courage, on the basis of such limited experience, to advise against reduction in these cases; but an optimistic attitude must be adopted, whether reduction is performed or not. Careful nursing and physiotherapy are necessary from the beginning. These patients must no longer be discharged from busy surgical wards on the grounds that the outlook is hopeless.

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should be made through healthy bone and, therefore, when the bone at the site of the deformity is abnormal, it is necessary to go just above or just below the site of the maximum deformity). The base of the wedge is determined from the preliminary roentgenogram and, as a matter of routine, it is always slightly larger than necessary in order to ensure an easy correction. The wedge includes the cortex on the three sides of the bone The cortex remaining on the one side is drilled once or twice with a three-sixteenths-inch drill. Very gentle pressure is then applied to the bone in question to make sure that slight bending occurs at the site of the osteotomy. The wedge of bone is then cut up into small pieces, and replaced in the defect The periosteum is carefully closed This is a simple matter in growing bone, but in adult bone it requires more care. Often the periosteum is only a filament-like layer attached to the adjacent muscle, but it will still serve as a limiting membrane and possibly as an osteogenic layer if properly protected. The remaining soft parts are closed in a routine manner; the usual

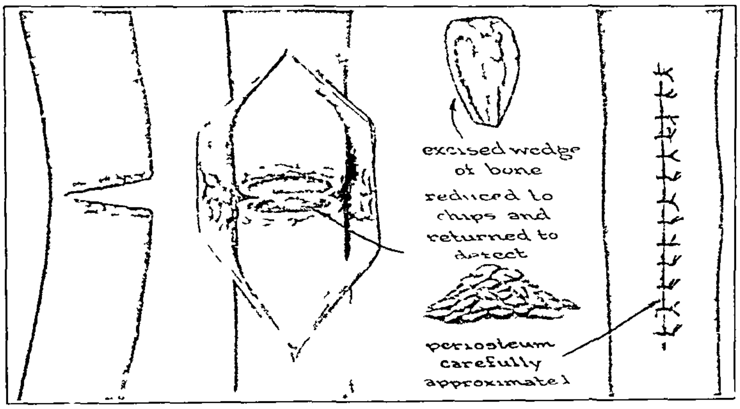

FIG 2

Sketch showing wedge, chips, and careful closure of the periosteum

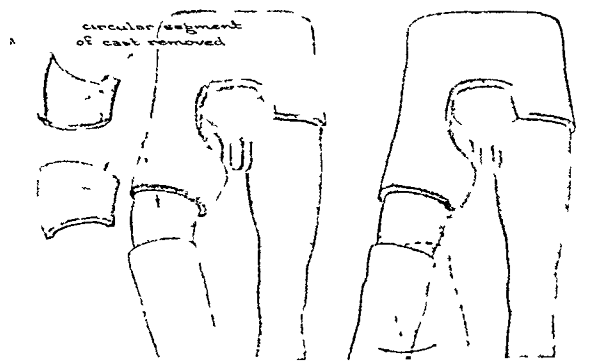

FIG 3

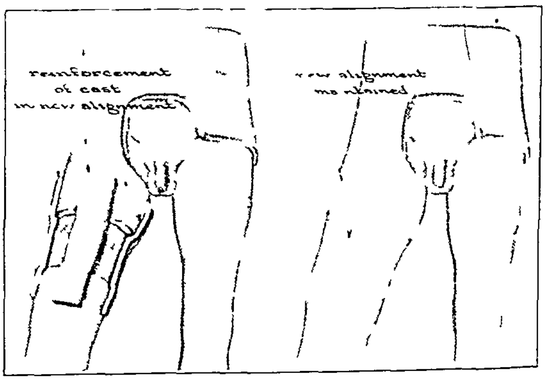

FIG 4

Fig 3 Sketch illustrating removal of section of cast in preparation for osteoclasis
Fig 4 Cast following osteoclasis Note circular section being repaired

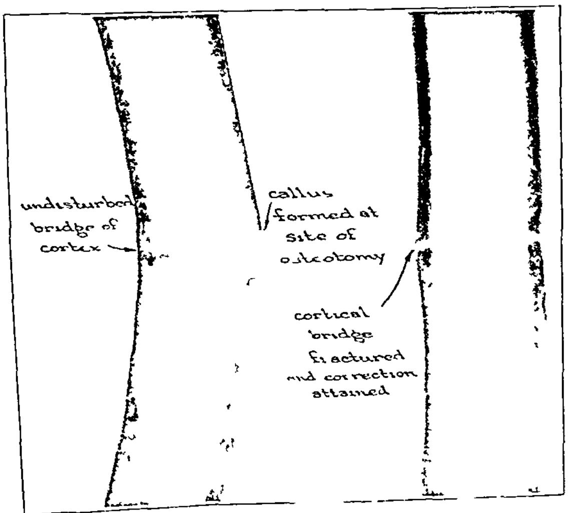

FIG. 5

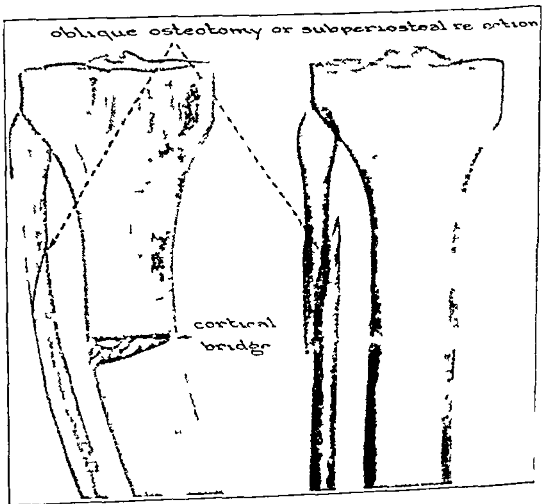

FIG 6

Fig 5 Sketch showing ring callus following osteoclasis
Fig 6 Showing special technique employed in deformities of the upper end of the tibia

S

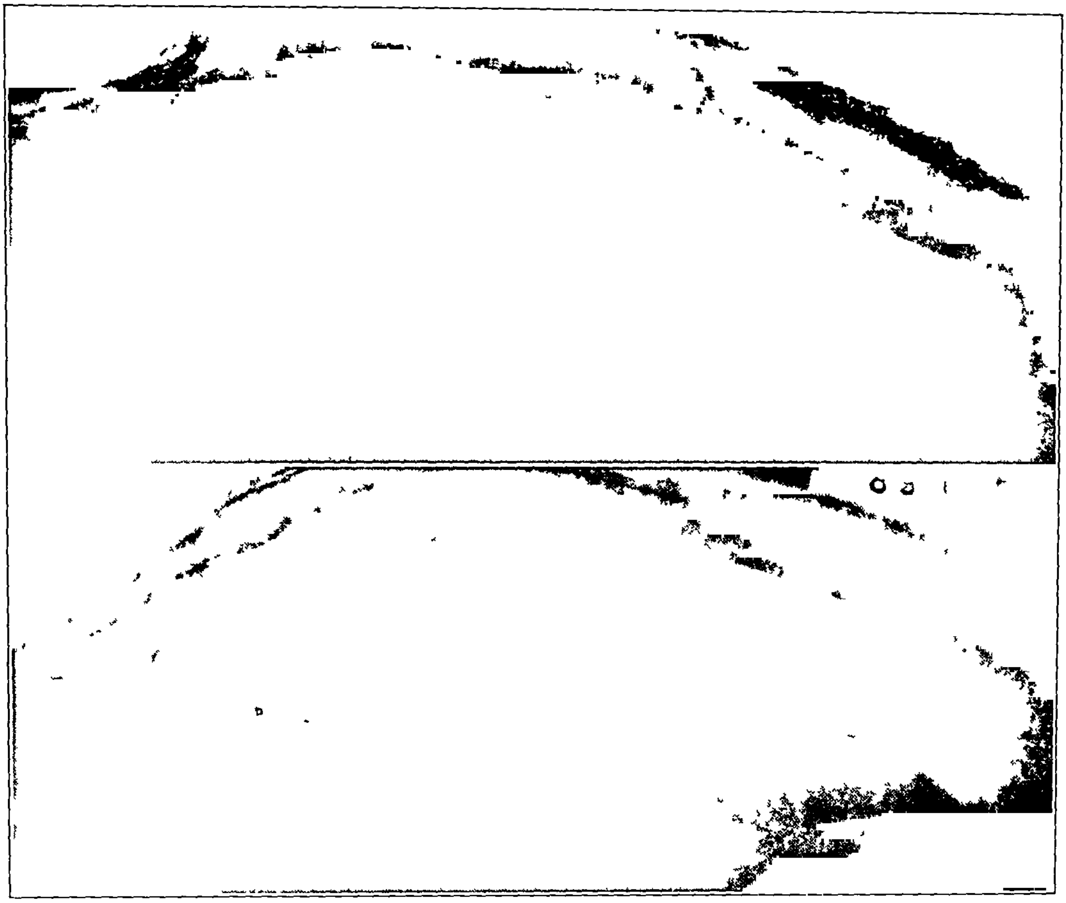

FIG. 10-B

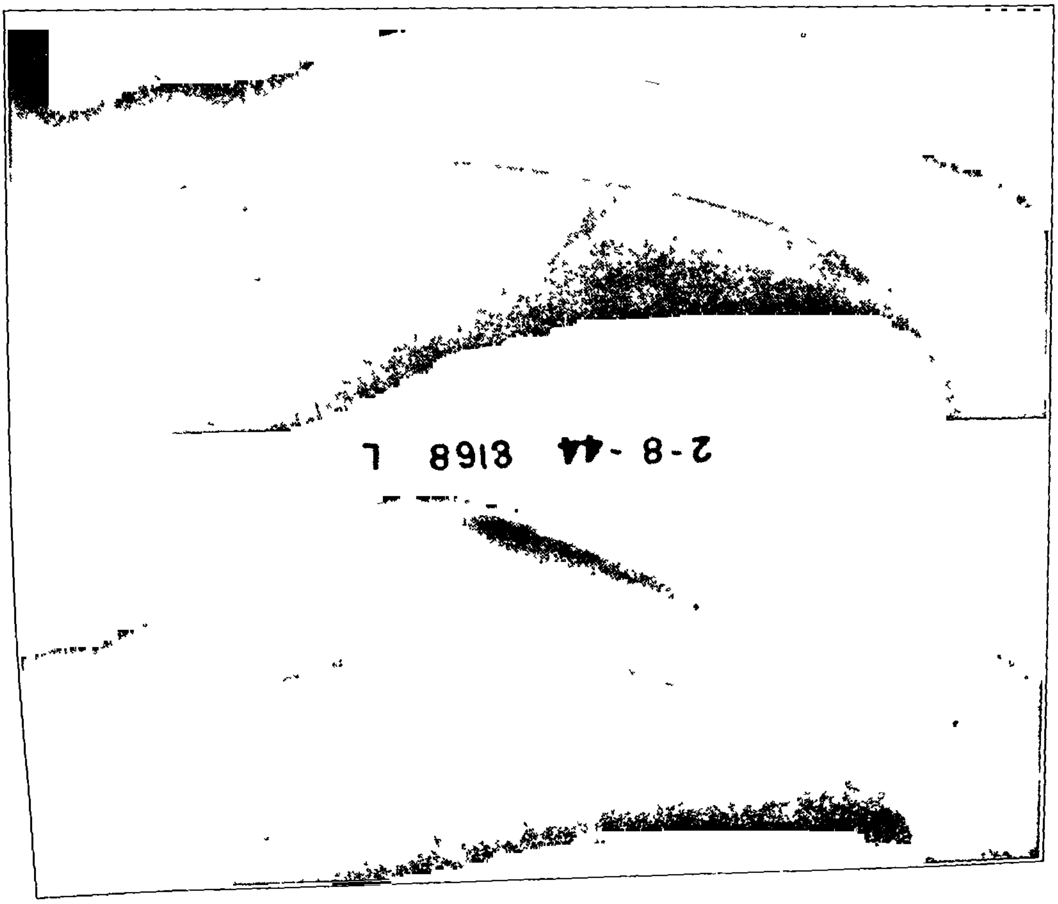

FIG. 10-A

FIG. 10-A. E. M., aged thirteen years. Anteroposterior and lateral roentgenograms, taken February 8, 1944, showing severe bowing deformity of the left femur, middle third.
FIG. 10-B: February 16, 1944. Anteroposterior and lateral views, showing the incomplete osteotomy.

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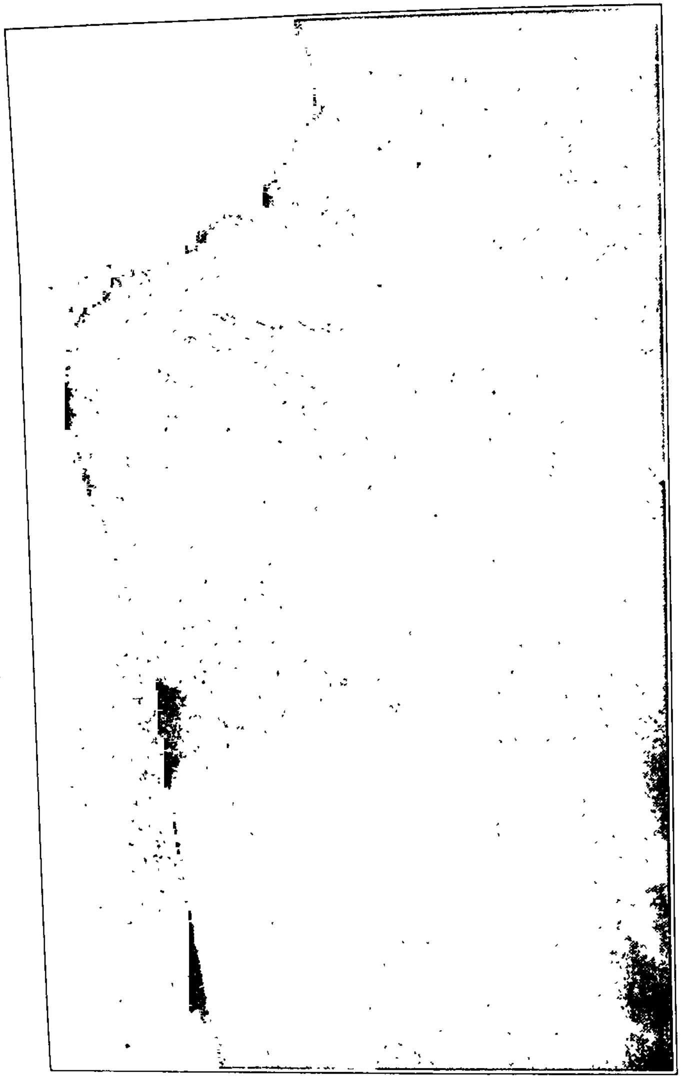

Fig. 11-A

Fig. 11-B

Fig. 11-A: Mrs. C. S., aged thirty-seven years. Roentgenogram, taken May 22, 1944, showing incomplete osteotomy at the junction of the middle and upper thirds of the shaft of the femur.

Fig. 11-B: June 28, 1945. Anteroposterior and lateral views of the osteotomy site, approximately twelve months following osteoclasis. Note absence of displacement.

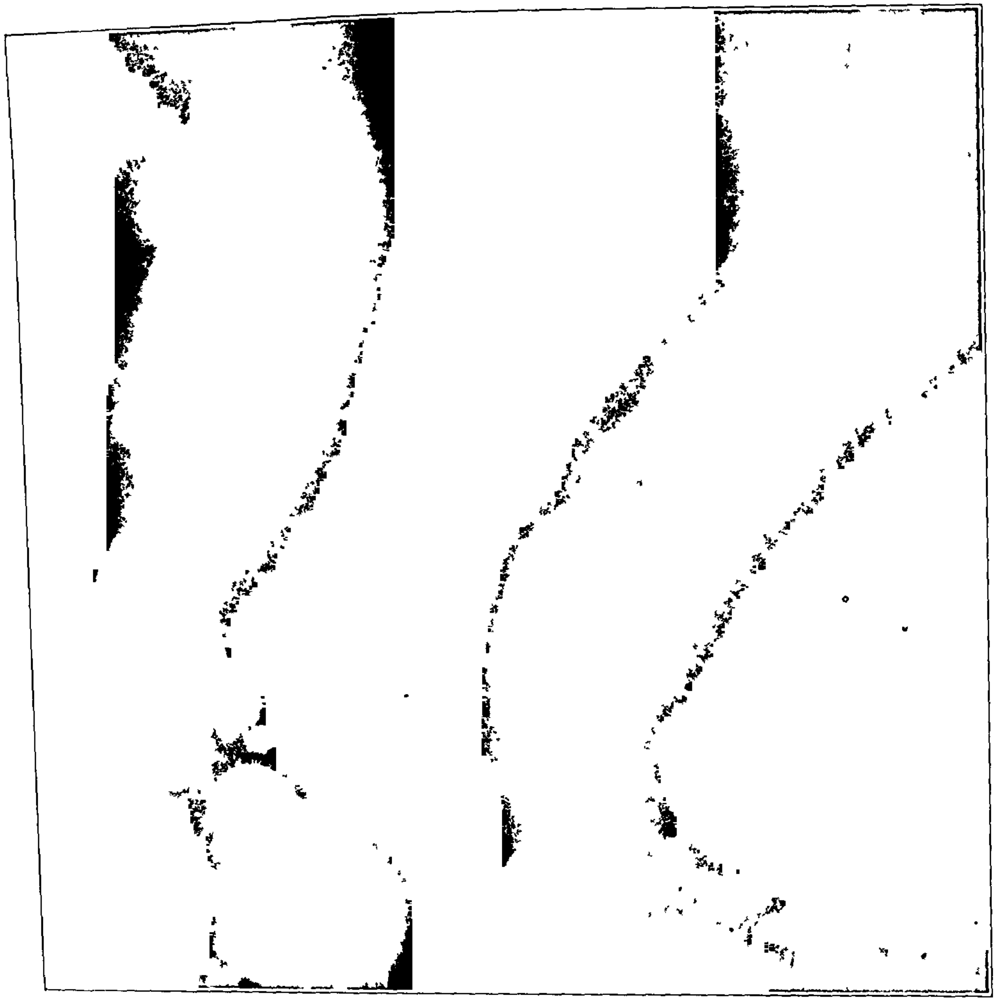

Fig. 13-A

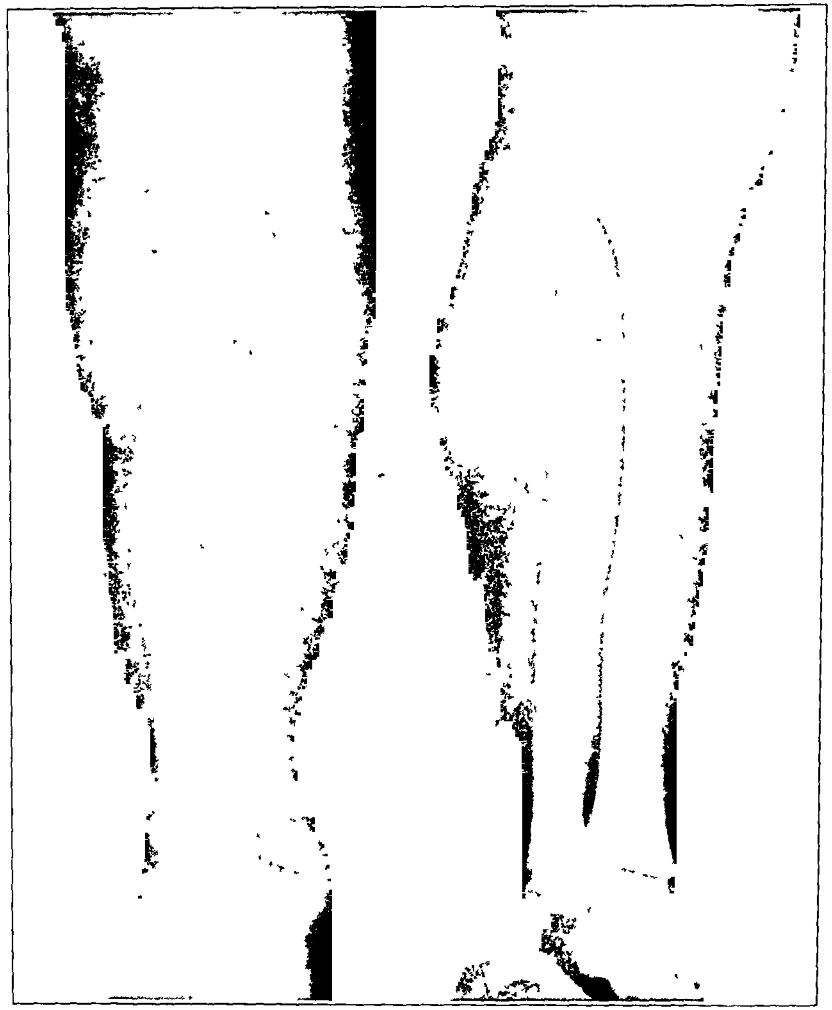

Fig. 13-B

Fig. 13-A: C. H., thirteen months old. Anteroposterior and lateral roentgenograms taken November 25, 1944, showing congenital anterior and medial bowing deformity at the lower end of the left tibia.

Fig. 13-B: June 13, 1946. Anteroposterior and lateral views of the left tibia and fibula, eighteen months after the osteoclasis. Note the absence of any displacement. Slight lateral bowing still persists.

OSTEOTOMY-OSTEOCLASIS

A Method for Correcting Long-Bone Deformities

BY JOHN ROYAL MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

Numerous methods for the correction of deformities of the long bones are available in recent and old textbooks and in the literature. In 1878 Macewen described what is now known as the cuneiform osteotomy, employing it at that time for the correction of knock-knee deformities. Numerous other types of osteotomies including linear, circular, block, pivot, Z, telescoping, *et cetera* have been described. One of the principal difficulties in the correction of long-bone deformities has been the problem of prevention of displacement of the fragments. This factor, more than any other, has been largely responsible for the innumerable types of osteotomies, only a few of which have been mentioned in the preceding sentence. In recent years, internal fixation has been used to supplement the various types of osteotomy and has gone far toward eliminating the difficulty of slipping. However, the necessity of larger incisions, the usual hazards associated with more difficult surgery, the increased danger of infection, and the risk of necrosis (electrolytic, thermal, and ischaemic) have detracted considerably from the mechanical advantages.

The osteotomy-osteoclasis method consists simply in cutting the long bone almost entirely in two, near or at the site of the maximum deformity, and then completing the osteotomy by manual osteoclasis at a later period (twenty-one days in growing bone and twenty-eight days in adult bone). The osteotomy-osteoclasis routine was first employed upon a severely malunited subtrochanteric femoral fracture, at the Shriners' Hospital for Crippled Children, Philadelphia, Pennsylvania, in 1934. A careful review of the literature has supplied no reference to this osteotomy-osteoclasis routine, but it is highly probable that it has already been described.

Osteotomy and osteoclasis are well-known procedures, usually done as separate operations and occasionally combined at one operation. In July 1939, Ferguson, Thompson, and King reported a two-stage osteotomy.

A total of 225 operations of this type have been performed to date. The long-bone deformities consisted of malunited fractures, ankylosed joints with severe deformity of one type or another, knock-knee, bow legs, coxa vara, humerus varus, cubitus varus, *et cetera*.

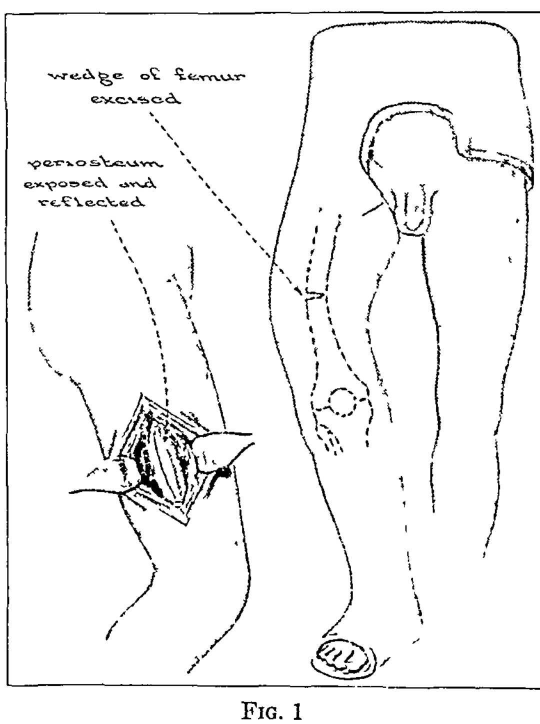

FIG. 1

Drawing illustrating incision, incomplete osteotomy, and immobilizing cast.

TECHNIQUE

A characteristic of the method is its simplicity. The site of the maximum deformity is approached through the most direct route. A linear incision, six to eight centimeters long, is made over the site of the deformity. Routine surgical technique is employed through subcutaneous tissue, fascia, and muscle, and down as far as the periosteum. The periosteum is then split carefully and preserved with the utmost care. A wedge of bone is removed, either at the site of the maximum deformity or just above or just below it (the osteotomy

FIG. 15-A

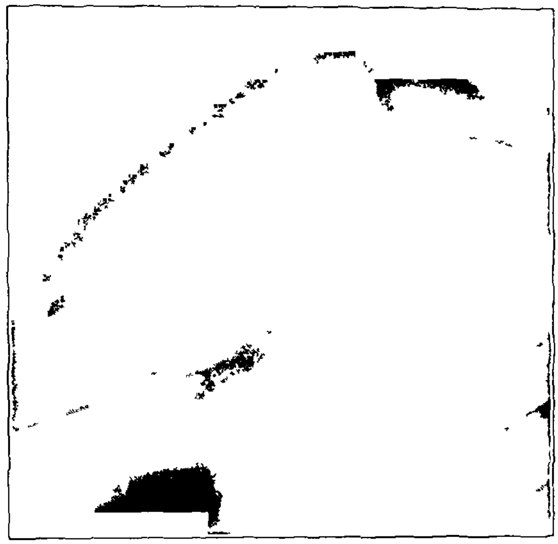

FIG. 15-B

Fig 15-A A. K., aged fifteen years. May 20, 1943. Anteroposterior roentgenogram of the right humerus, upper third, illustrating a severe lateral bowing deformity.

Fig 15-B · September 22, 1943. Anteroposterior view, four months later. Note the correction of the deformity, lack of displacement, and early evidence of repair.

disturbance,—venous, arterial, or lymphatic. The sketches are illustrative of the method; and the roentgenograms show some of the typical results.

DISCUSSION

Osteotomy-osteoclasis is extremely valuable in the correction of angulations, bowings, and rotary deformities of long bones. It obviously cannot be employed to gain length, other than the apparent lengthening that follows the correction of the angulation of a bowing deformity. The incision employed is small; and the closure is extremely simple, since there is no distortion of soft parts, because the correction of the deformity is done *immediately. The approach is simple; and the time required for the wedge osteotomy* is only a few minutes. This minimizes the risk to older people.

The author has employed the procedure a number of times in the correction of deformities of people beyond sixty years of age. The fact that there are two periods of anaesthesia is objectionable, but the total anaesthesia time is much below the total employed in the usual osteotomy in the adult. It is not usually necessary to apply the splint or the plaster at the time of operation; this can be added two or three days after the operation if necessary. In no instance has the patient objected to the second anaesthesia. Follow-up roentgenograms are taken immediately after the osteotomy and, in case it is too low or too high, the defect may be allowed to heal and the osteotomy may be repeated at the proper level at a later period. In case there is infection in the neighborhood—such as about the hip or the knee—which does not respond to treatment, hence theoretically postponing correction of a severe deformity indefinitely, it is possible to do the incomplete osteotomy at a slightly lower level with a feeling of safety; and, should infection occur, it is considerably less dangerous, because the osteotomy is incomplete. The osteotomy may serve as a means of testing a dormant infection in an old scar. The delayed osteotomy produces distinctly less shock, and hemorrhages have never been an accompanying problem. In case the deformity involves two bones, as in the forearm or leg, it is necessary to do the incomplete osteotomy on both of the bones and preferably at the same level, and, of course, in the same axis. In deformities of the upper tibia, a resection of the proximal end of the fibula facilitates the osteotomy-osteoclasis of the tibia. The fact that there is no appreciable displacement at the time of the osteotomy should be strongly emphasized. Another important point is the fact that an absolutely perfect alignment can be obtained through a check by fluoroscope (no correction is done under fluoroscope). The fact that

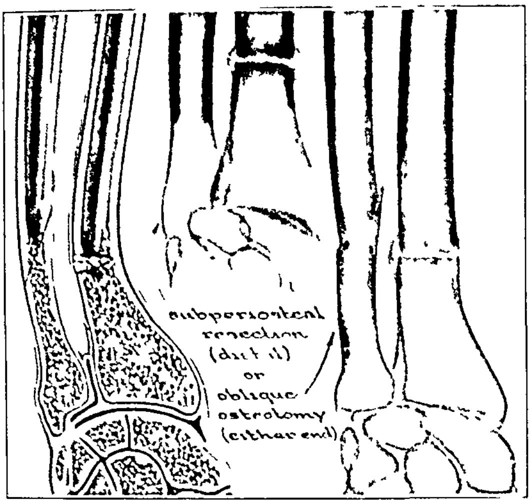

Fig 7

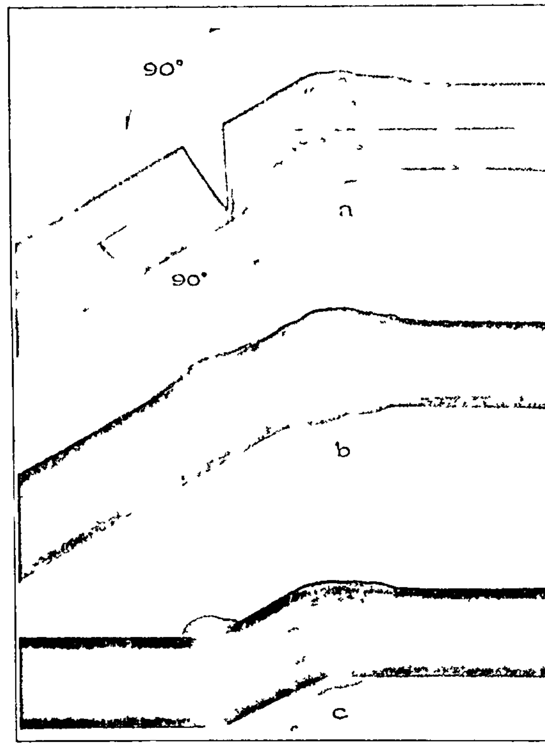

Fig 7 Sketch illustrating technique employed in deformities of the lower end of the tibia

Fig 8 Incomplete wedge osteotomy being employed just below fracture site. Bone at fracture site is sclerotic and is not considered proper for osteotomy.

Fig 8

dressing is applied; and a plaster-of-Paris splint or cast is applied, including the joint below and the joint above the osteotomy site. The anaesthesia period is rarely longer than ten or fifteen minutes and any of the standard anaesthetics may be employed.

At the end of twenty-one days in an individual with growing bone and twenty-eight days in the adult, the patient is again returned to the hospital; and a cylindrical section of the cast is removed at the site of the incomplete osteotomy. The true axis of the wedge is determined by preliminary roentgenograms and, if necessary, it is checked by fluoroscope The patient is given a light anaesthetic, and the osteoclasis is performed It is extremely important that the axis of the wedge be determined, so that the gentle force takes place along the proper axis. The intact bone is easily broken. The correction of the deformity is then readily accomplished, and with a minimal amount of displacement of the fragments. The defect in the plaster is then filled in with slabs and circular plaster. The long bone of the child is held for an additional six weeks and that of the adult for eight to twelve weeks, depending upon the level of the fracture (fracture in midshaft in an adult for twelve weeks, cancellous bone in an adult for eight weeks).

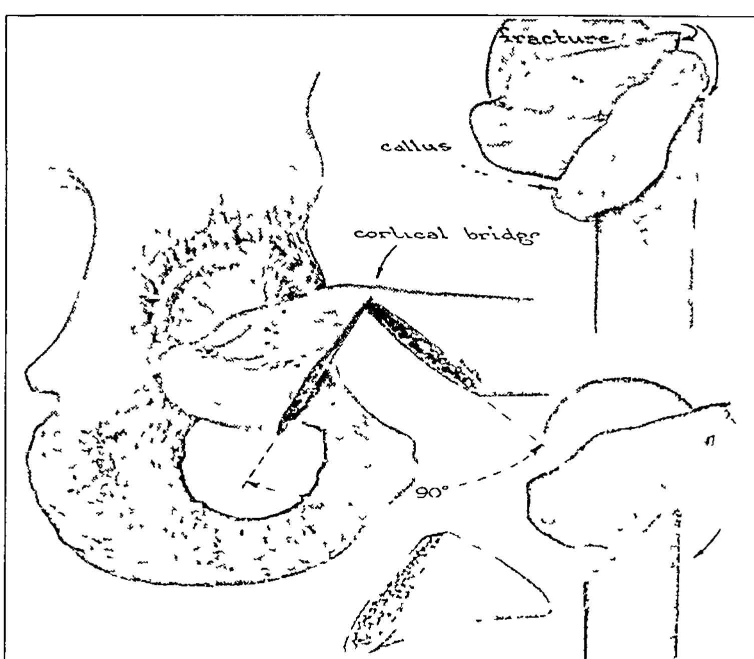

Fig 9

Sketch illustrating technique employed in severe flexion deformity at the hip. Note location of wedge.

FRACTURE-DISLOCATION OF THE ANKLE WITH FIXED DISPLACEMENT OF THE FIBULA BEHIND THE TIBIA*

BY DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

From St. Luke's Hospital, New York City

In the past eighteen months, five cases of fracture-dislocation of the ankle joint have been seen, in which satisfactory reduction could not be accomplished by closed methods. On open exposure, a situation was found which, to the author's knowledge, has not previously been reported. It is probable that many other such cases occur, and that bad results ensue, due to lack of knowledge of the basic mechanical situation.

The first patient was seen in December 1944. Roentgenograms showed a typical bimalleolar fracture, with marked displacement (Fig. 1-B). On attempted closed reduction,

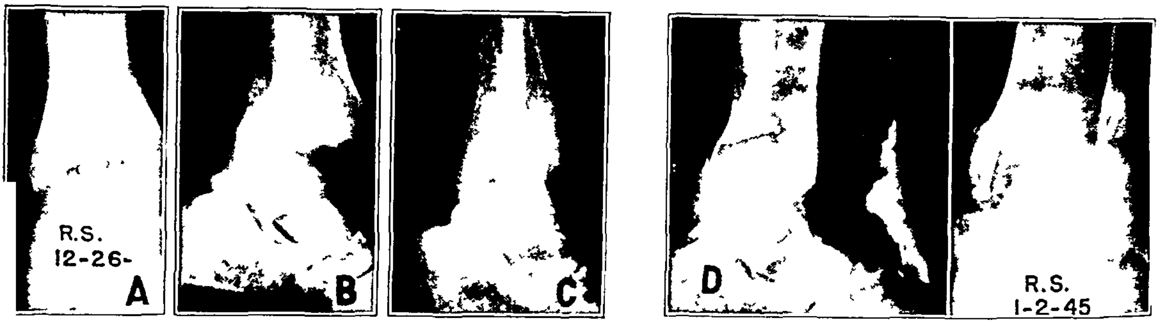

Fig. 1-A Fig. 1-B Fig. 1-C Fig. 1-D

Fig. 1-A: Faulty reduction, secured in fracture-dislocation of the ankle when the upper fibular fragment was caught behind the tibia.

Fig. 1-B: Original roentgenogram of fracture-dislocation of the ankle.

Fig. 1-C: Lateral view, following attempt at closed reduction, shows faulty position of talus beneath tibia.

Fig. 1-D: Postoperative reduction, after fibula had been pried from behind tibia and the fragments had been fastened with screws.

poor reposition of the talus beneath the tibia was secured, and even this could not be maintained (Figs. 1-A and 1-C). An open exploration was done, and even at operation it was impossible to determine at first why reduction could not be secured. Upon further extension of the incision, it was found that the proximal portion of the fibula had been displaced behind the tibia and was caught in back of the posterolateral ridge of the tibia. The fibula was held in this position by the tight stress of the interosseous membrane above A pry was inserted between the tibia and fibula; and, with considerable force, the fibula was pried out from in back of the tibia and moved into its proper place with a loud snap. Reduction of the fracture-dislocation was then secured easily.

In February 1945, Henry Briggin, M.D., called about a patient with fracture-dislocation of the ankle in whom the fibula alone was involved. He had attempted to do two reductions by aid of the fluoroscope within half an hour of the time of injury, but was unable to replace the talus satisfactorily beneath the tibia. Indeed, when he had obtained the reduction as nearly as possible, the blood supply to the rest of the foot was lacking A diagnosis was immediately made of posterior fixation of the fibula behind the tibia; and at operation, a few hours later, this situation was found to be present. The fibula was pried out from its displaced location, and the talus could easily be replaced beneath the tibial border (Figs. 2-A, 2-B, and 2-C). In both of these instances, metal fixation of the fractured malleoli was done.

* Read before the Orthopaedic Section of the New York Academy of Medicine, New York City, May 18, 1945; and at the Annual Meeting of The American Orthopaedic Association, Hot Springs Virginia, June 28, 1946.

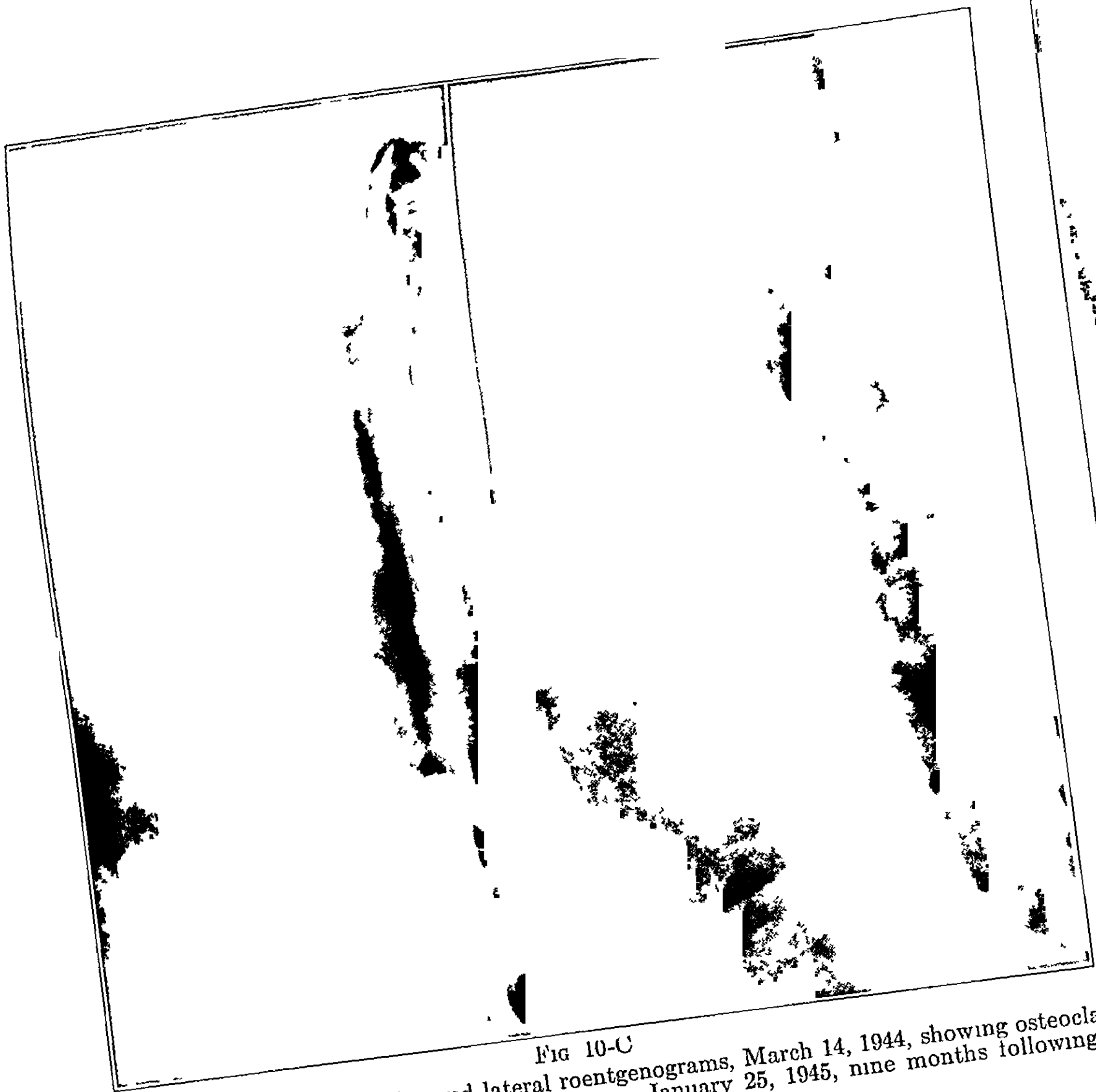

Fig 10-C

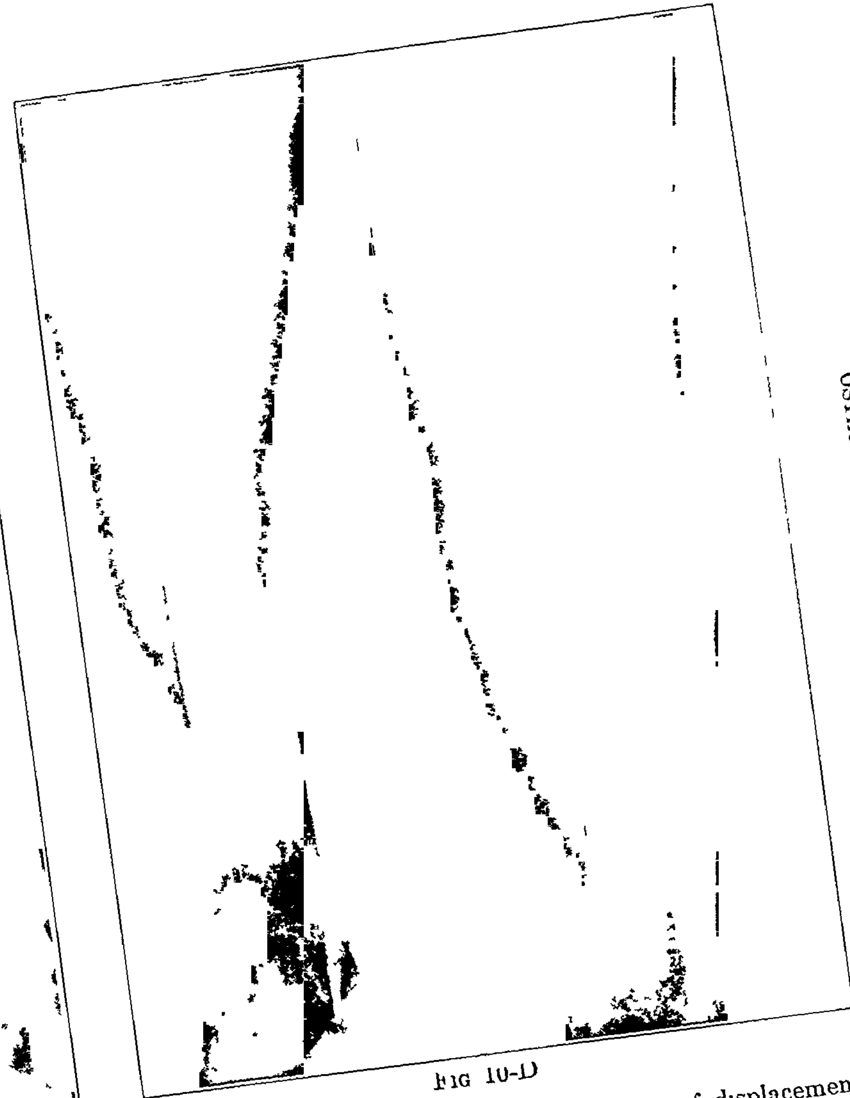

Fig 10-D

Fig 10-C Anteroposterior and lateral roentgenograms, March 14, 1944, showing osteoclasis
Fig 10-D. Anteroposterior and lateral views, January 25, 1945, nine months following osteoclasis. Note perfect alignment and absence of displacement.

relief of pain. From this, one can see the importance of recognizing the occasional case with posterior displacement of the fibula behind the tibia.

Two other similar cases of fracture-dislocation of the ankle, with posterior fixation of the fibula behind the tibia, have been seen. One patient, a woman, continued under conservative care, with the talus displaced laterally under the tibia, for two years. The malleoli became united with the tibia and fibula, but traumatic arthritic changes occurred

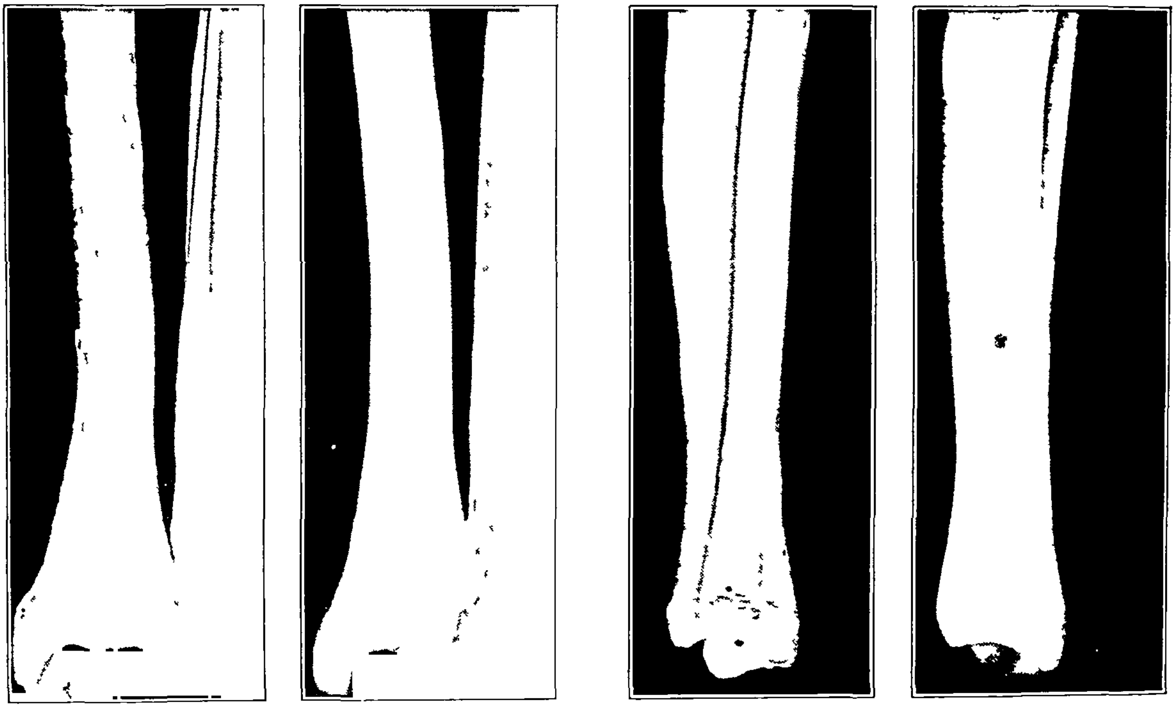

Fig. 4-A

Normal relationship of fibula and tibia, as shown by photographs and roentgenograms

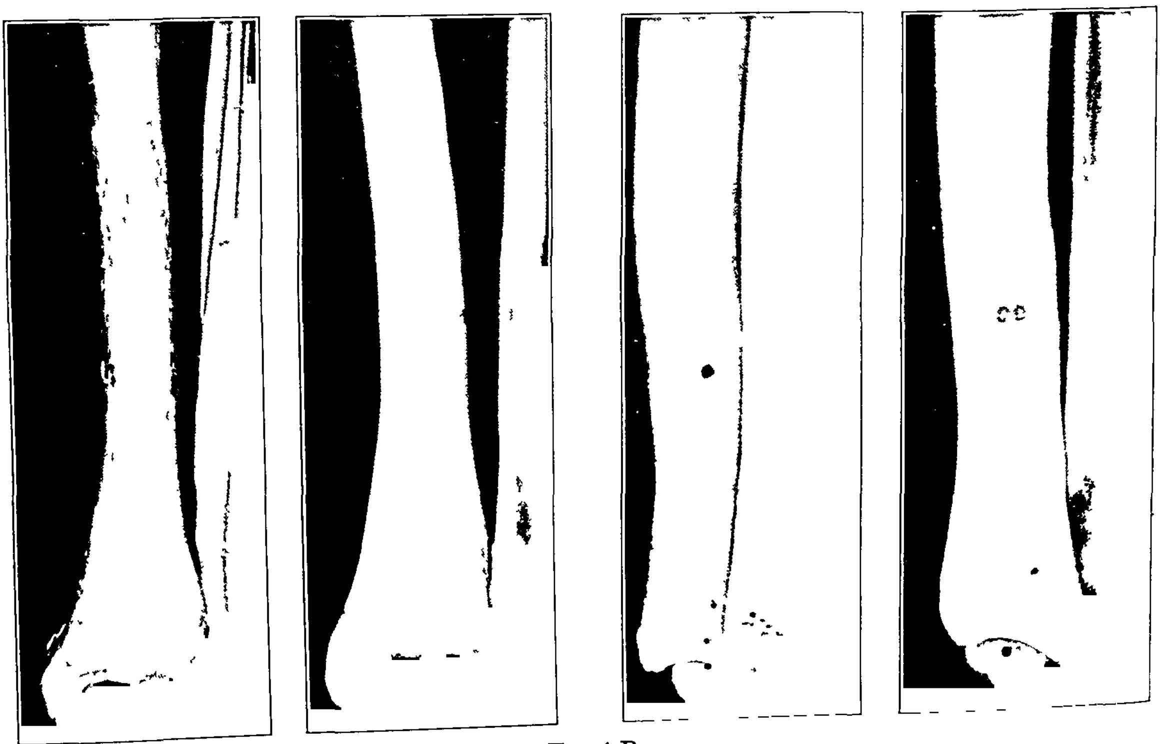

Fig. 4-B

Proximal fibular fragment has been displaced behind the posterolateral ridge of tibia (shown in photograph). Roentgenograms show no change from the normal on the anteroposterior view, and but slight change on the lateral view.

RESULTS

Of the 225 cases reported, there has been no evidence of non-union, malunion, or slipping or displacement of fragments at the time of the osteoclasis. There has been no evidence of fat embolism or embolic phenomena of any kind. There has been no circulatory

Fig. 12-A

J. E., aged twenty-one years. Roentgenogram, taken May 10, 1944, showing bony ankylosis of the right hip. Note adduction deformity; severe 80-degree flexion deformity was also present.

Fig 12-B

Lateral and anteroposterior views of osteotomy site, October 3, 1944, five months later. Note union, excellent alignment, and lack of displacement.

one will find that it passes transversely between the two bones instead of in an anteroposterior direction, because of the displaced osseous structures. A great amount of force is necessary for replacement, even with a pry. The reason all such fractures do not have the upper fragment of the fibula impacted behind the tibia is that, in most of them, the fibula breaks off (due to leverage against the lateral surface of the tibia) before it has been swung backward over the posterolateral tibial ridge. The interosseous membrane is undoubtedly too tough and tight in most instances to allow displacement of the fibula to occur before the fracture takes place.

Photographs and roentgenograms of an articulated specimen of a tibia and a fibula show that, on the lateral view in normal position, the tibia and fibula become superimposed and lie almost in the same straight line (Fig. 4-A). It has always been felt, in interpreting roentgenograms, that the fibula would be at a posterior level, because the medial malleolus is anterior to the lateral malleolus. This is not so, since the medial malleolus really arises from the front half of the medial surface of the tibia. When the fibula is slightly displaced and caught behind the posterolateral ridge only (Fig. 4-B), on the anteroposterior view it appears to be in its normal position on the lateral surface of the tibia. The lateral views, both in the photographs and the roentgenograms, show that the fibula is truly caught behind the lateral ridge of the distal portion of the tibia. Oftentimes roentgenograms are interpreted as showing no displacement of this upper fibular fragment, because it is believed by the roentgenologist that the view taken was not truly lateral or

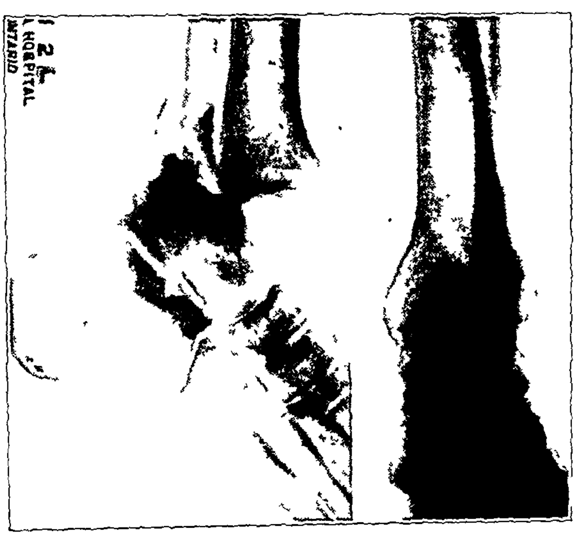

Fig. 1-A (Harris)

Fig. 1-B (Harris)

Fig. 1-C (Harris)

Fig. 1-D (Harris)

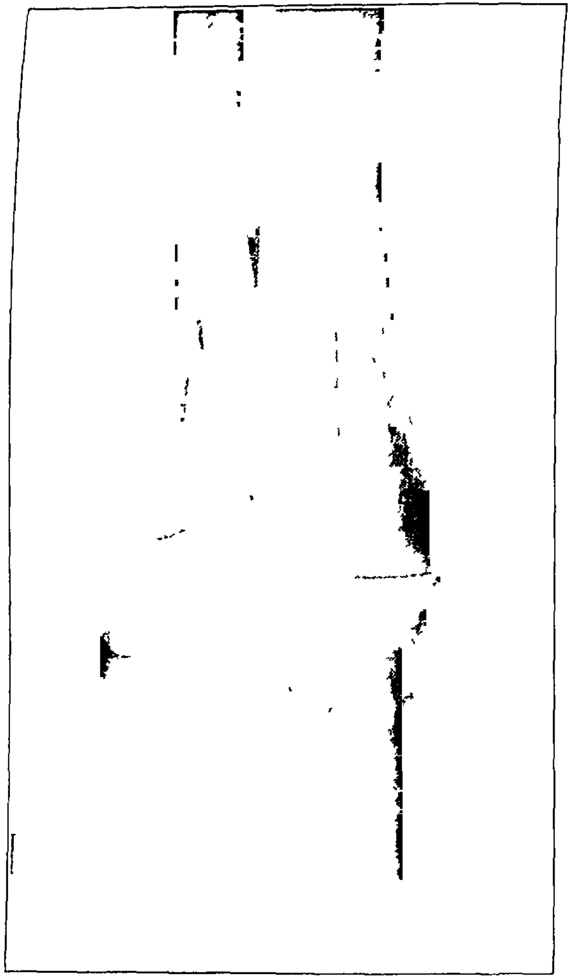

FIG. 14-A

FIG. 14-B

Fig. 14-A: J. H., aged twenty-four. Anteroposterior view of the right ankle joint, taken January 10, 1946, shows bony ankylosis of the talotibial joint and malunited bimalleolar fracture.

Fig. 14-B: May 16, 1946. Anteroposterior and lateral views of the right ankle, five months after osteoclasis.

THE FORMATION AND SIGNIFICANCE OF VERTEBRAL ANKYLOSIS IN TUBERCULOUS SPINES

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In reviewing the cases of tuberculous spondylitis at this Clinic, the author noted that in a few cases the clinical healing of the process coincided with the roentgenographic appearance of a spontaneous fusion of the anterior spine. In the cases where a prolonged roentgenographic follow-up was available, it was observed that these vertebral synosteoses, or vertebral blocks, had been formed either by end-to-end contact of two or more vertebral bodies after the destruction of the intervertebral disc and cartilaginous plates, or by recalcification and union of the remnants of several vertebral bodies which had been partially destroyed during the early stages of the disease.

The amount of concurrent deformity of the spine, and the shape, structure, and speed of formation of these synosteoses, were not uniform. In some cases, they appeared in only slightly deformed spines, and after periods of from two to three years; while in others, the fusion of the anterior spine took place when a marked kyphosis was already present, the formation of the block requiring a much longer period of time.

Interest in these vertebral blocks was aroused by the fact that the best clinical results in cases of tuberculous spondylitis were observed in the cases which healed with a minimum amount of deformity of the spine and with the formation of an osseous block which included all the infected vertebral bodies. Follow-up of these cases, for long periods of time after the clinical signs of activity had disappeared, failed to show either recurrence of the disease or increase of the deformity. Consequently, a study was made of the conditions under which the blocks were formed, to determine if they had any relationship to the age of the patient, the location of the lesion, or the number of bodies involved. From a practical point of view, especial interest concerned the possibilities of obtaining the blocks at will, either by conservative or surgical procedures.

Careful study of the spines which healed by the formation of vertebral synosteoses showed that three main factors regulated the speed of their formation and final configuration: the topographical distribution of the infection, the pathomechanics of the different spinal segments, and the treatment.

A. *Types of Tuberculous Spondylitis*

The types of tuberculous spondylitis vary according to the topographical localization of the primary focus. They have been given several names: Kaufmann described a cortical and a central tuberculous spondylitis; Loeffler spoke of a "spondylitis tuberculosa anterior superficialis" and of a "spondylitis tuberculosa anterior profunda"; Ménard divided the types into "cavernous" and "intervertebral"; Steindler described the anterior peripheral, the central, and the epiphyseal forms; Calvé and Galland described the group of the "osteites vertébrales centrosomatiques". Finally, Seddon introduced the term of "metaphysial tuberculosis" and Hellstadius that of "paradiscal tuberculosis".

In spite of the confusion produced by differences in terminology, it is evident that nearly all the writers agree that there is a definite relationship between the localization of the primary focus and the ultimate characteristics of the spondylitic process. The explanations of the variation in the site of the primary focus have been based on the studies of Lexer and his associates of the blood supply of the vertebral bodies. This subject has more recently been reviewed by Wagoner and Pendergrass. The different sources of blood supply

* Service of Arthur Steindler, M.D.

the wound is closed makes it possible to correct the angulation or bowing in both planes, and to correct the rotary deformity in a way similar to that used in any flexible tubing.

CONCLUSIONS

The writer feels that the method for the correction of long-bone deformities described is fundamentally sound; that it is applicable in the correction of any of the long-bone deformities; and that it should be employed to the exclusion of major surgery and extensive internal fixation whenever possible.

NOTE: Even though the first osteotomy-osteoclasis was performed in 1934 when a preliminary report was given by the writer, twelve years were allowed to elapse, in order to accumulate a sufficiently large group of cases for an analysis of the results.

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In the so-called epiphyseal or paradiscal tuberculous spondylitis, the process appears on roentgenograms either as a progressive thinning of the intervertebral disc, with or without the presence of a circumscribed focus of osteitis, localized near the intervertebral space, or as a destructive process, extending all along the paradiscal region of one or two contiguous vertebral bodies. The rest of the vertebral body preserves its normal shape and structure, except for slight signs of decalcification. In the central types of tuberculous spondylitis, where the body as a whole presents signs of marked decalcification and softening, different phenomena occur.

In the first group of cases described, the resistance to pressure stresses of the infected vertebral bodies was not greatly diminished. In all the cases of tuberculous epiphyseal spondylitis, the patients had been walking and working for one or more years before seeking treatment, and in none was a collapse of the vertebral bodies observed. On the other hand, among the cases of central spondylitis, a massive flattening of one or more vertebral bodies was prone to occur, even while the patients remained in recumbency.

Another factor that influences the final shape of the vertebral synosteosis is the appearance of the protective muscle spasm; from the onset, it produces a complete flattening of the lordosis in the lumbar spine, thus allowing a uniform telescoping of the vertebral bodies in the cases of the epiphyseal type.

Finally, the amount of destruction that takes place in each body, the number of affected bodies, and the type of treatment are factors in the final configuration of the vertebral blocks. These factors will be described in detail in the study of the clinical cases.

From the study of this series of cases, no conclusions were reached regarding the relationship between the final shape of the synosteosis and the different pathological types of berculous spondylitis (productive, caseous, fibrocaseous, *et cetera*).

3. Treatment

The evaluation of the effects of the treatment upon the speed of the formation and final configuration of the different types of vertebral synosteosis was made through the roentgenographic study of our clinical cases. From them we selected only those that fulfilled the following conditions:

1. Cases which had had roentgenographic check-up every three months, not only during the active stage of the process, but for several years after a clinical cure had been obtained;
2. Cases that had healed by the formation of a synosteosis on the anterior spine;
3. Cases of tuberculous spondylitis proved by guinea-pig inoculation of pus obtained from an abscess; or, in the cases without superficial abscesses, patients with a typical clinical and roentgenographic process, plus a proved tuberculosis of some other part of the body;
4. Cases without secondary infections or sinus tracts.

Sixty-one spondylitic lesions fulfilled the above requirements. Cases of adult and infantile tuberculosis were studied separately. More detailed data about localization, age of the patients, and clinical characteristics, will be given in the discussion of each of the different groups.

TUBERCULOUS SPONDYLITIS IN ADULTS

1. Formation of Vertebral Synosteoses in Cases of so-called Epiphyseal Spondylitis

Twenty-five spondylitic foci were found. In twenty of them the tuberculous process was proved by positive guinea-pig inoculations. In the remaining five, the possibility of any other type of infection was ruled out repeatedly by the clinical and roentgenographic progress, agglutination tests, blood cultures, *et cetera*. In addition, each of these patients had an associated proved tuberculosis in some other region of the body.

The lumbar region was involved seventeen times; the thoracic spine in five cases; the

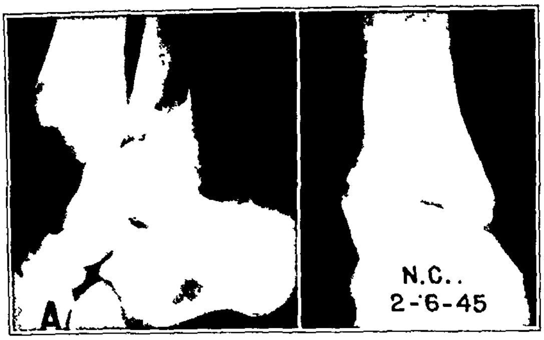

Fig. 2-A

Fig. 3-A

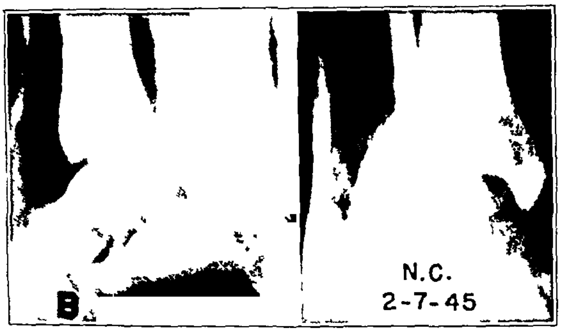

Fig. 2-B

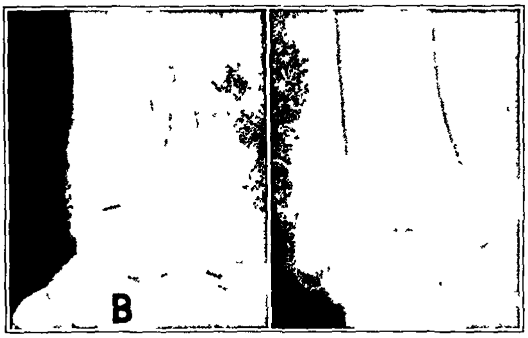

Fig. 3-B

Fig. 2-C

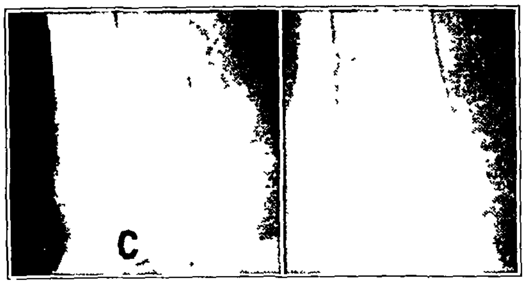

Fig. 3-C

Fig. 2-A: Fracture-dislocation of the ankle before reduction, with fibula caught behind postero-lateral ridge on tibia.

Fig. 2-B: Showing the best closed reduction that could be secured. At the time these roentgenograms were taken, the foot circulation was shut off by mechanical pressure of the fibula against the posterior vessels.

Fig. 2-C: Reduction has been obtained by open operation, use of a pry, and fixation of the lateral malleolus with a screw.

Fig. 3-A: Original reduction of fracture-dislocation of the ankle, with fibula caught behind tibia. Roentgenograms show incomplete reposition of talus beneath tibia.

Fig. 3-B: Result of fifth attempt at closed reduction. Faulty reposition of talus under tibia and widened ankle mortise are shown.

Fig. 3-C: Final result in a fracture-dislocation of the ankle, with fibula caught behind tibia. Attempt at closed reduction was unsatisfactory. Solid malunion was present before ankle fusion was done.

The third case was seen at the Mary Fletcher Hospital in Burlington, Vermont. The patient appeared with the typical clinical findings of malunion of a fracture-dislocation of the ankle, which involved the lateral malleolus alone. Roentgenograms showed incomplete reduction of the talus beneath the tibia and the typical findings of posterior displacement of the upper fragment of the fibula behind the tibia, although to the casual observer the fibula did not appear so displaced (Figs. 3-A, 3-B, and 3-C). Reductions had been done on November 17 and December 1, 1944; two reductions were done on December 3; and an attempt at re-reduction was made on December 11. In desperation, the surgeon finally accepted the bad situation. The cast was still in place when the patient was first seen by the author, four months later. Arthrodesis of the ankle joint was done for disability and

thoracolumbar junction in three cases. The average age of the patient at the time of onset was twenty-six, the youngest being nineteen and the oldest thirty-seven. Associated tuberculosis of the lungs was present in fourteen. The pulmonary process began two to three years before the spinal symptoms in six cases; in one it started six years before. In the remaining cases, the pulmonary involvement was discovered in the routine chest plates, taken in the examination of every case of suspected osseous tuberculosis.

In twenty cases there was a subcutaneous abscess, this being the first clinical sign in three of them.

Except for those that were already in recumbency for some other type of tuberculosis, most of the patients were seen for the first time one or two years after the onset of the clinical symptoms. None had had any previous treatment, and all had been walking and working up to the time of admission.

All these patients were treated by prolonged periods of conservative treatment. Following this, if the general condition, roentgenograms, and laboratory tests showed that the condition was in the healing stage, and no other active tuberculous focus was present in another part of the body, a fusion of the spine was performed. The technique used was the one described by Steindler. Following the surgical fusion, the patient remained in a plaster bed from three to four months, following which he was allowed to get up with a body cast for about three months, and finally a body brace was applied.

This series does not include cases treated exclusively by an early surgical fusion of the posterior spine. However, there were fifteen cases which were treated only by conservative measures, due to the presence of some other active extraspinal tuberculous focus, which necessitated keeping the patient in recumbency. During this time, a spontaneous fusion of the anterior spine occurred, and a surgical intervention was not performed.

Roentgenographically, three groups were most frequently seen:

First, there were cases characterized by a progressive and slow thinning of one intervertebral space. This thinning was usually accompanied by a subcutaneous abscess, and after three to four years the two vertebral bodies became directly superimposed (Fig. 1). The outlines and structure of the vertebral bodies remained very distinct throughout the duration of the process; and, in spite of the close contact, no osseous trabeculae running from one vertebral body to another were seen. These unions were considered to be fibrous unions.

Secondly, there were the cases characterized by the presence of a small destructive focus, localized immediately below or above the intervertebral space. If in the roentgenogram this focus appeared in the center of the body, the evolution of the process was usually identical to those just described. However, if the anteroposterior or lateral view showed that this destructive area was localized near the margins, after a period of thinning of the disc lasting between one and two years, a partial and osseous synosteosis between the vertebrae appeared (Figs. 2 and 3). As a rule, after this synosteosis had taken place, the remaining intervertebral space was spared. These unions were classified as partial osseous blocks.

Finally, there were the cases in which the destructive process was extended all along the paradiscal region of one or two vertebral bodies. The destruction of the intervertebral disc, as observed in the roentgenograms, was slow but complete; the two vertebrae became approximated by telescoping and the end result was a total and osseous union of two vertebral bodies (Figs. 4-A and 4-B). In some of these cases, the process started in one body and spread to the contiguous one; in others, the process started simultaneously in both of them, a phenomenon which can be explained on the basis of the characteristics of the arterial circulation. As demonstrated by Hanson and later by Solotuchin, the same branch of the posterior vertebral artery supplies the apposing surfaces of two contiguous vertebral bodies.

Peripheral new-bone formation was observed in only four cases without sinuses,

FIG. 4-C

Roentgenograms confirm the photographic findings of marked posterior displacement of the fibula behind the tibia. With the osseous structures of the foot and the lateral malleolus in place, faulty roentgenographic interpretation is generally made, even in this grossly displaced situation, because the interpreter believes the picture was taken in rotation or at an angle.

in the ankle joint and pain persisted. Two years after the fracture, the patient was seen by the author and ankle fusion was performed.

A police officer, who was seen nine months after injury, had union of the fibular fracture and widening of the tibial mortise. A diagnosis was made of posterior fixation of the fibula behind the tibia; at operation, this diagnosis was confirmed. The widening of the tibial mortise could not be overcome, even with the lateral malleolus separated entirely from the fibula above and from all other structures except the collateral ligament, until the proximal fragment had been displaced from behind the tibia and returned to its normal location. This was apparently due to the traction attachment of soft tissues from the talus and calcaneus to the proximal fragment of the fibula. Since the patient was an active and youthful person, reconstruction of the ankle mortise was attempted by simple fixation of the fibular fragments with screws. Six months after the operation, this patient returned to light police duty and has no demonstrable defects in or about the region of his damaged ankle.

The author believes that the situation described arises as follows: As the foot twists under the talus, with the leg continuing to push forward and to rotate outward, the lateral collateral ligaments draw the intact fibula behind the tibia. Continuation of the force rotating the talus backward and out from its position beneath the tibia causes further force on the lateral collateral ligaments; finally, the fibula is broken off against the posterior tibial border, as one would break a bone over a wedge in doing an osteoclasis. Following the fracture and the cessation of the forces, there is nothing left attached to the upper fragment of the fibula by which it can be drawn back into place. One may tear off the periosteum and swing the talus under, or nearly under, the tibia. It is impossible, however, to force the upper fibular fragment back around the posterolateral ridge on the lower tibia, because of the tight pull of the still intact interosseous membrane. b insertion of a pry between the two bones will enough leverage be produced to fibula in its proper location on the lateral surface of the tibia. Upon insertin

the recumbent period for completion of the vertebral block. The posterior surgical fusion can be used in these cases as a means of increasing the spinal stability, and thus obtaining a better protection during the first months of resumed activities. However, it is interesting to remember that, as Seddon obtains similar results by the use of a body brace, the surgical fusion should not be considered essential and should be used only in the cases in which, due to the localization of the process, complete immobilization cannot be obtained with a body brace.

The prognosis of these blocks was excellent, regardless of type. Not only was the amount of spine deformity minimal, but observations over periods ranging from two to ten years after the clinical arrest of the process, failed to show signs of collapse or reactivation of the process. This was true in the cases surgically fused, as well as in the cases treated conservatively throughout.

2. *Formation of Vertebral Synosteoses in Cases of Central Tuberculous Spondylitis*

The tuberculous infection may spread inside the vertebral body, producing a diffuse tuberculous osteomyelitis. In some cases observed during the early stages of the disease, the lesion was clearly localized at the center of the vertebral body, and later produced a secondary involvement of one of the intervertebral spaces. However, in most of the cases seen several months or years after the onset of the clinical signs, it was impossible to ascertain the localization of the primary focus. In only two cases of this group of central spondylitis did the process start as a progressive thinning of the intervertebral disc. They differed from the ones belonging to the group of epiphyseal spondylitis, in that the disappearance of the intervertebral space, as seen in the roentgenogram, was complete six months after the onset of the clinical symptoms.

Fifteen spondylitic lesions which fulfilled all the requirements already described were included in this study. Three of them were proved cases of tuberculosis by guinea-pig inoculation of pus obtained from a paravertebral abscess. There was an active tuberculosis of the lungs in ten cases, of the kidney in two, and of the hip in one.

The age of the patients was between seventeen and fifty-three, the average being twenty-six years. The lesion was localized in the lumbar spine in four cases; and in the thoracic segment, in eleven cases. In all of these eleven thoracic cases, abscesses were evident in the roentgenograms. None of these abscesses became superficial.

In five cases the pulmonary symptoms started two years before the spinal ones. In one case, the pulmonary infection was discovered two months prior to the spondylitic lesion. In the others, the lesions were found during the routine check-up on admission.

In all cases the original lesion was confined to two vertebral bodies, with total destruction of their corresponding intervertebral spaces. In only two cases did the process invade two additional vertebral bodies before reaching the healing stage. Widespread destruction of multiple vertebral bodies and intervertebral spaces was not observed, even in the cases in which there was a secondary anterior involvement of several vertebrae above and below the primary focus.

There were several factors that made the formation of a vertebral block somewhat different in these cases from those belonging to the group of paradiscal spondylitis: First, the roentgenographic disappearance of the intervertebral space was a rapid phenomenon, as was also the spreading of the infection into the two contiguous vertebral bodies. Second, due to the more intense destruction of the vertebral bodies, the appearance of wide gaps between the spinal segments was frequently observed. Third, the intrinsic resistance of the vertebral bodies was diminished in such a way that the phenomenon of sudden collapse was prone to appear. Fourth, anterior involvement of several bodies above and below the primary focus was frequently seen. Fifth, central or peripheral new-bone formation, intense enough to fill the gap between the remnants of the vertebral bodies, after the destructive period was over, was never observed; and, consequently, the formation of a block

truly anteroposterior. In the badly displaced upper fibular fragment (Fig. 4-C), there should be no difficulty in interpreting the roentgenograms properly, if the roentgenologist understands that posterior fixation of the fibula behind the tibia can occur in fracture-dislocation of the ankle. Actually, the interpretation is generally wrong, because the possibility of such a situation has not occurred to the roentgenologist.

Having these facts in mind, if one reviews the roentgenograms for the first three cases presented here, it will be noted in each instance that gross discrepancies appear in the roentgenograms, pathognomonic of posterior dislocation of the fibula behind the tibia, and that in no preoperative roentgenogram shown was the fibula clearly seen to be in its normal relationship to the tibia.

SUMMARY

In fracture-dislocation of the ankle, one should make sure that the upper fragment of the fibula is not caught behind the posterolateral ridge of the tibia. In some instances, fracture of the lateral malleolus does not occur until the foot has twisted beneath the ankle joint, drawing the fibula behind the tibia and breaking it off against the posterior margin thereof. When this occurs, the fibula is firmly caught and needs open reduction with a pry; severe disability is likely to occur unless accurate replacement is made by operative means.

DISCUSSION

Dr. R. I. Harris, Toronto, Ontario, Canada: A recent experience, fresh in my memory, is clarified by Dr. Bosworth's presentation. It can best be presented by illustrations. Figure 1-A shows the fracture-dislocation sustained by a farmer, forty-seven years old. In Figure 1-B is seen the result obtained by manipulations. Figure 1-C shows the best result which could be obtained by repeated manipulations.

Open operation was undertaken. The lower end of the upper fibular fragment was deeply buried behind the tibia. It was fixed firmly in this position, and strongly resisted replacement. Unlike Dr. Bosworth, we did not detect the true state of affairs. Strong leverage finally shifted the fragment, which then suddenly snapped back into something like its normal position. It was secured to the lower fragment by a suture of stainless-steel wire. The result of the operation is shown in Figure 1-D.

I now recognize that this difficult fracture problem was of the type described by Dr. Bosworth. It is well that it should be recorded, for I feel certain that his observations will explain hitherto unsatisfactory results.

increase of the deformity, reactivation of the process, or phenomena of sudden collapse.

As far as spine deformity is concerned, the end results could have been much better in a high percentage of cases. One of the main reasons for the failure to control deformity was the inability to determine the exact moment when the patient should resume the standing position. As a rule, they were allowed to get up before the vertebral block was capable of withstanding daily stresses, sudden collapse sometimes occurring a few weeks afterward (Figs. 7-A and 7-B). For this reason, it was important to determine what roentgenographic signs differentiate an *unsound* vertebral block from one capable of preventing further increase of the deformity. The conclusion was reached that a vertebral block, appearing after a central spondylitis, cannot be considered *sound*, unless it fulfills the following requirements:

1. The outlines should be sharp and well defined. In the cases where a central cavity is present (Fig. 6), the outlines of this cavity should also be sharp and well circumscribed.
2. The density of the vertebral block, as shown by roentgenogram, should be equal to that of the surrounding non-affected vertebrae.
3. No signs of erosion should be present in either the upper or the lower articular surfaces of the newly formed vertebral body.
4. No paravertebral soft-tissue shadows should be present, especially if the lesion is localized in the thoracic segment.

In the thoracic and thoracolumbar segments, a block with all these characteristics was obtained only after from five to seven years of recumbent treatment. The question arises as to whether we are justified in keeping a patient in recumbency for such a long period of time, or if it is possible to obtain similar results in a shorter period by surgical fusion of the posterior spine.

The advantages and disadvantages of fusing a tuberculous spine have been discussed in detail by Steindler, and consequently only a brief résumé of our findings is necessary. Our conclusions are based on a comparative study of the end results in the patients fused after a vertebral block had been obtained and those fused and allowed to get up before an anterior synosteosis had occurred. The findings were as follows:

1. In cases of central spondylitis when the patient had been treated by recumbency

Fig. 7-A

Fig. 7-B

Fig. 7-A: A case of bilateral pulmonary tuberculosis and tuberculosis of one knee. The lateral view showed what appeared to be a solid block, formed by two partially destroyed vertebral bodies. The patient was allowed to get up with a brace two years after the onset of the spinal symptoms.

Fig. 7-B: Roentgenograms taken three months after the patient was allowed to get up showed a pathological fracture. She had not had any injury during the interval.

to the different parts of a vertebral body will explain the different topographical types, which, in spite of the complex variety of names suggested, may be basically reduced to three: anterior, central, and epiphyseal.

In recent years, several authors (including Schmorl, Seddon, Junghanns, and Doub and Badgley) have taken exception to the term "epiphyseal tuberculosis", and several other terms have been proposed as substitutes. There is no doubt that the term "epiphyseal" is incorrectly used in most of the cases; because this particular type of tuberculous spondylitis appears frequently in adults after the secondary centers of ossification of the vertebral bodies have already fused, and very seldom is the process confined to the so-called vertebral epiphysis. On the other hand, the recent studies of Schmorl and Junghanns tend to deny that the secondary centers of vertebral ossification are true epiphyses. For these reasons, the term "metaphysial tuberculosis" (Seddon) or that of "paradiscal tuberculosis" (Hellstadius), is more in accord with our present knowledge of anatomy. This latter term will be used frequently, because it does not infer the accepted existence of a true vertebral epiphysis, meaning only a tuberculous process localized at the portion of the vertebral body contiguous to the intervertebral disc.

B. *Pathomechanics of the Tuberculous Spine*

In order to understand the final configuration and the mechanism of formation of the vertebral blocks, it is necessary to take into consideration the pathomechanics of the different spinal segments.

Due to the fact that, in tuberculous spondylitis, new-bone formation is as a rule nonexistent or very slight, the formation of a vertebral synosteosis is possible, in the great majority of cases, only after the approximation and superimposition of the affected vertebrae have taken place. This approximation can be performed either along a longitudinal axis (telescoping), by flexion in the sagittal plane of one spinal segment upon the other (called "inflexion" by Ménard), or, in a minimum number of cases, by flexion in the frontal plane (the so-called tuberculous scoliosis).

As described in detail first by Ménard and more recently by Calvé and Galland, due to some anatomical peculiarities, the amount of telescoping and "inflexion" that may take place between two vertebral bodies varies in the different segments of the spine. In the lumbar region, because of the size of the discs, the vertical position of the articular facets, and the relative narrowness of the pedicles, a marked amount of telescoping may take place. Conversely, the telescoping is minimum at the thoracic segment. In the cervical spine, the interposition of the transverse processes, after the destruction of the vertebral bodies has taken place, interferes with the telescoping.

As far as the tendency towards forward flexion is concerned, the maximum possibilities are found in the thoracic spine. In this segment, the loss of the nucleus pulposus produces a posterior displacement of the center of motion between the two vertebrae, a subluxation at the level of the articular processes, and an increase of the amount of body weight to be supported by the anterior part of the vertebral body. Later, if a complete destruction of one or more vertebral bodies has taken place, the orientation of the thoracic articular facets will allow the backward and downward displacement of those neural arches that have lost their connections with the anterior spine, thus producing a still further increase of the deformity.

None of these peculiarities is present in the cervical and lumbar segments where, as a rule, the deformities are much less pronounced. In the cervical segment, especially, the "inflexion" is always incomplete, because of the interposition of the transverse processes.

However, these regional characteristics alone cannot explain the differences in the final configuration of the different vertebral blocks. There are several other factors that should be taken into consideration; one of these is the decrease in the resistance of the body of the vertebra to pressure stresses, secondary to some types of tuberculous spondylitis.

In three cases, the infection involved three vertebral bodies. The pattern of formation was quite uniform. After the acute stage was over—during which the centrally situated body practically disappeared—recalcification took place and two of the affected vertebrae united, forming a block which was unsound because it did not include all the diseased vertebral bodies. A sound block was obtained two or three years later, which included all the affected vertebral bodies (Figs. 8-A, 8-B, and 8-C). Observations from three to six years after resumption of activities demonstrated a complete healing of the process.

In twelve cases, the process involved four or five contiguous vertebral bodies In these cases the final shape of the block was directly related to the amount of compression and wedging suffered by the two or three vertebrae most centrally situated. The two vertebral bodies situated at the extremes of the row, while presenting phenomena of erosion of the articular surface facing the center of the row, retained their normal structure and configuration fairly well. In the cases in which weight-bearing was not allowed until the most centrally situated bodies presented signs of good recalcification, the spine deformity was not too marked. On the other hand, if the patients were allowed to get up before this recalcification and final block formation had taken place, whether or not a spine fusion had been done, the most centrally situated

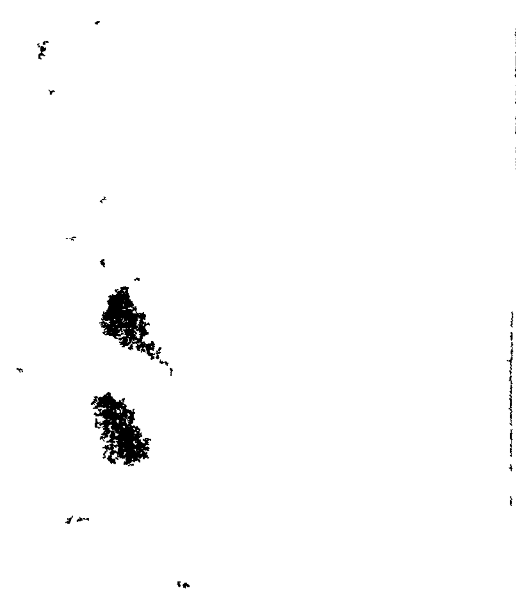

Fig 8-A
Showing affected vertebrae

Fig 8-B

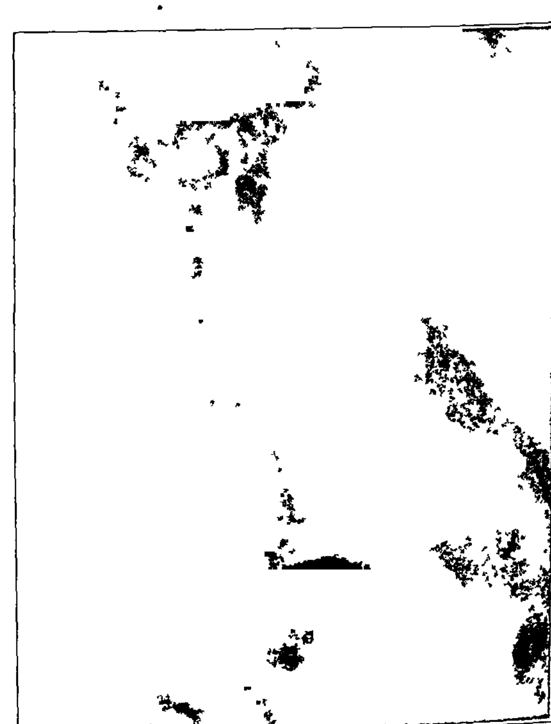

Fig 8-C

Fig 8-B: Spontaneous union of two vertebrae which proved unsound.
Fig 8-C: A sound block, including all the affected vertebrae, was later obtained

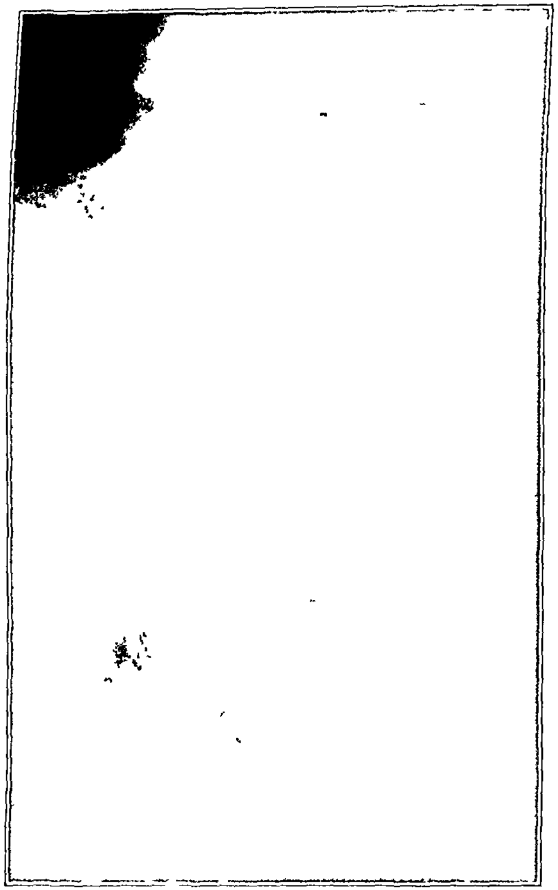

FIG. 1

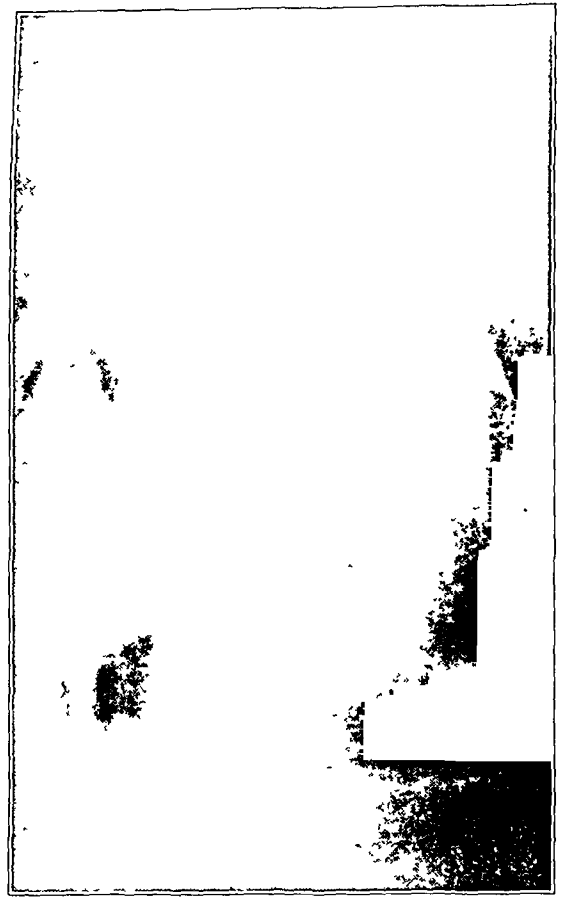

FIG. 2

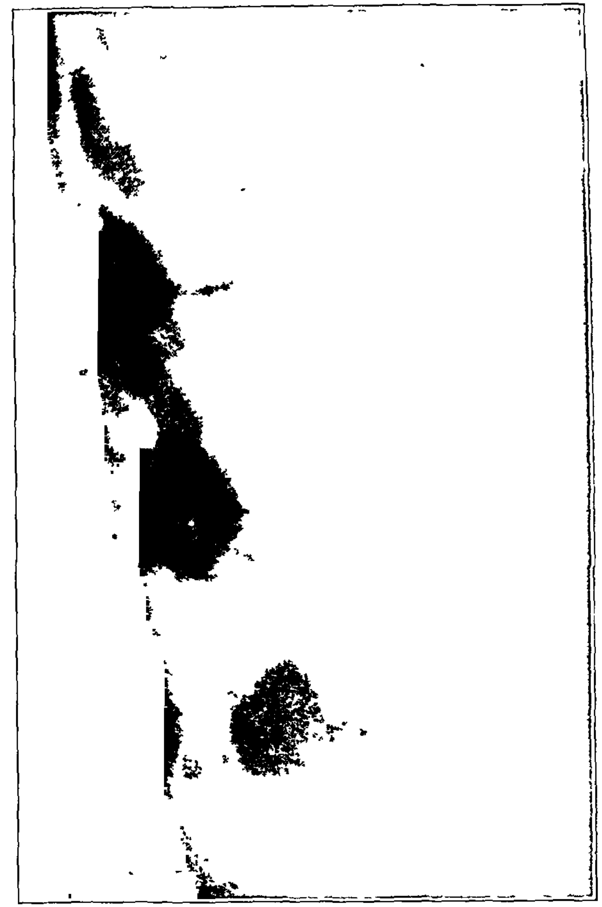

FIG. 3

Fig. 1: A case of tuberculous spondylitis proved by guinea-pig inoculation. Roentgenogram shows direct superimposition of two vertebral bodies after a slow and progressive thinning of the intervertebral disc for four years. No destructive osseous focus can be detected.

Fig. 2: Partial osseous union, localized at the anterior part of the vertebral bodies. As a space between the two vertebrae can still be observed, the destructive osseous focus was localized at the antero-inferior margin of the more cephalic vertebrae. The union was principally formed by peripheral new-bone formation and took place two and one-half years after the onset of the clinical symptoms. Patient had a proved tuberculosis of the kidneys and epididymis.

Fig. 3: Partial osseous union, occupying more than half of the intervertebral space. The posterior part of the intervertebral space is still visible. Original destructive focus was localized at the upper anterior region of the caudal vertebra. Patient had a proved tuberculous spondylitis, associated with pulmonary tuberculosis.

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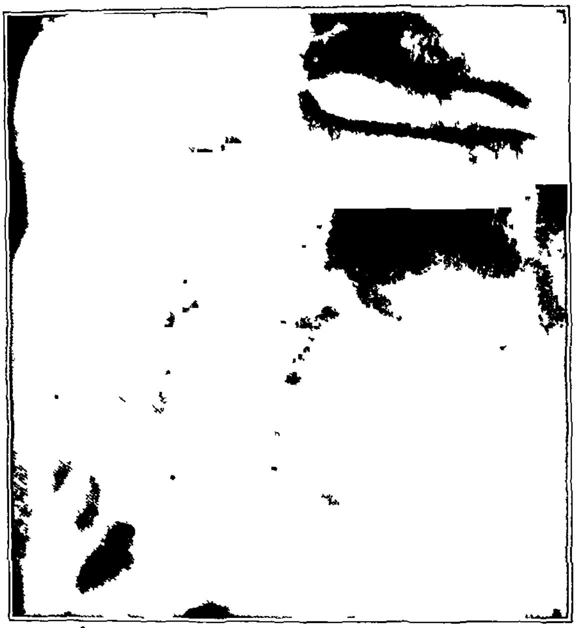

FIG 4-A FIG. 4-B

Complete osseous synostcosis of two vertebral bodies.

proved by guinea-pig inoculation. It appeared not earlier than one year after the onset of the clinical signs.

We were interested in knowing how much a posterior spinal fusion influenced the development of these blocks, especially from the point of view of accelerating their formation. For this purpose, the cases treated by prolonged recumbency alone and those treated by shorter periods of recumbency plus posterior surgical fusion, were compared. The conclusions obtained were as follows: (1) Independent of the type of treatment used, the roentgenogram showed that the type of vertebral block was related to the rapidity with which it was formed; (2) the surgical fusion of the posterior spine did not accelerate the formation of a vertebral block.

Under conservative or surgical treatment, the most rapid formation of vertebral synosteoses took place in the cases with circumscribed foci, localized near the margins of the vertebral bodies. Such a focus produced a partial osseous synosteosis in an average time of one and one-half years after the onset of the clinical symptoms. Next were the cases presenting a total destruction of the paradiscal regions; in these cases osseous ankylosis was complete in an average of three to four years after the onset of the clinical symptoms. Finally, in the cases characterized by a progressive thinning of the intervertebral space, fibrous union was obtained in from four to five years. The eventual transformation of this fibrous union into osseous synosteosis was observed in two cases, seven years after the onset of the clinical symptoms.

Some writers (Hibbs, Albee, Allison and Hagan) emphasize the point that a surgical fusion of the posterior spine should be performed as early as possible, in order to obtain the best result in tuberculous spondylitis. In our series there was only one case fused during the early stages; therefore, we are unable to confirm or deny this point. However, it is interesting to note that several authors (Calvé, McKee, Seddon) believe that the early application of an osseous graft will interfere with the future formation of the vertebral synosteosis.

From our experience, it may be stated that, if a posterior spinal fusion is performed when the process is in the healing stage and there is only a very small gap between the two involved vertebrae, it does not interfere with the final formation of a block. In other words, if the general condition of the patient allows him to be ambulatory and there are no other contra-indications arising from the vertebral lesion, it is not necessary to prolong

and luxation. Most of these differences, which are outlined in the schematic drawings (Figs. 2-A and 2-B), may be readily discerned on arthrograms.

The Acetabulum

In *subluxation,* the cartilaginous roof and the limbus, forced by the head of the femur against the external iliac fossa, always appear atrophied. By this pressure, the cavity is worn down in its upper part and generally takes on a "scooped-out" appearance, which is characteristic. This compression and atrophy of the cartilaginous roof present one of the essential points to be kept in mind in a consideration of the treatment of a subluxation.

In *luxation,* on the other hand, the cartilaginous roof and the limbus are forced toward the acetabulum. In such a case the limbus is always more or less hypertrophied. The appearance of the hypertrophied limbus in the arthrograms contributes to the creation of a constriction of the articular capsule, known as the "hourglass contraction". Moreover, the hypertrophied limbus frequently remains interposed between the head and the acetabulum during attempts at closed reduction of the luxation,—a point upon which I cannot enlarge in this article, which deals only with subluxation. However, apart from the interposition of soft parts, the acetabulum in a luxation generally retains a satisfactory depth with a well-developed roof. This fact has already been observed in England by Fairbank, as a result of the examination of the pelvis of subjects suffering from congenital luxation, who had reached an advanced age without any attempt at reduction having been made.

The worn down or shallow acetabulum, therefore, is the characteristic of subluxation, and not of luxation, as is stated in orthopaedic textbooks.

'he Head of the Femur

In *subluxation* the femoral head is deformed very early. It is enlarged, being widened transversely, as well as flattened at its supero-internal pole. This is shown in arthrograms of very young children, where the contour of the cartilage of the head, indicated by the contrasting medium, reveals this hypertrophy even when the osseous nucleus is poorly developed.

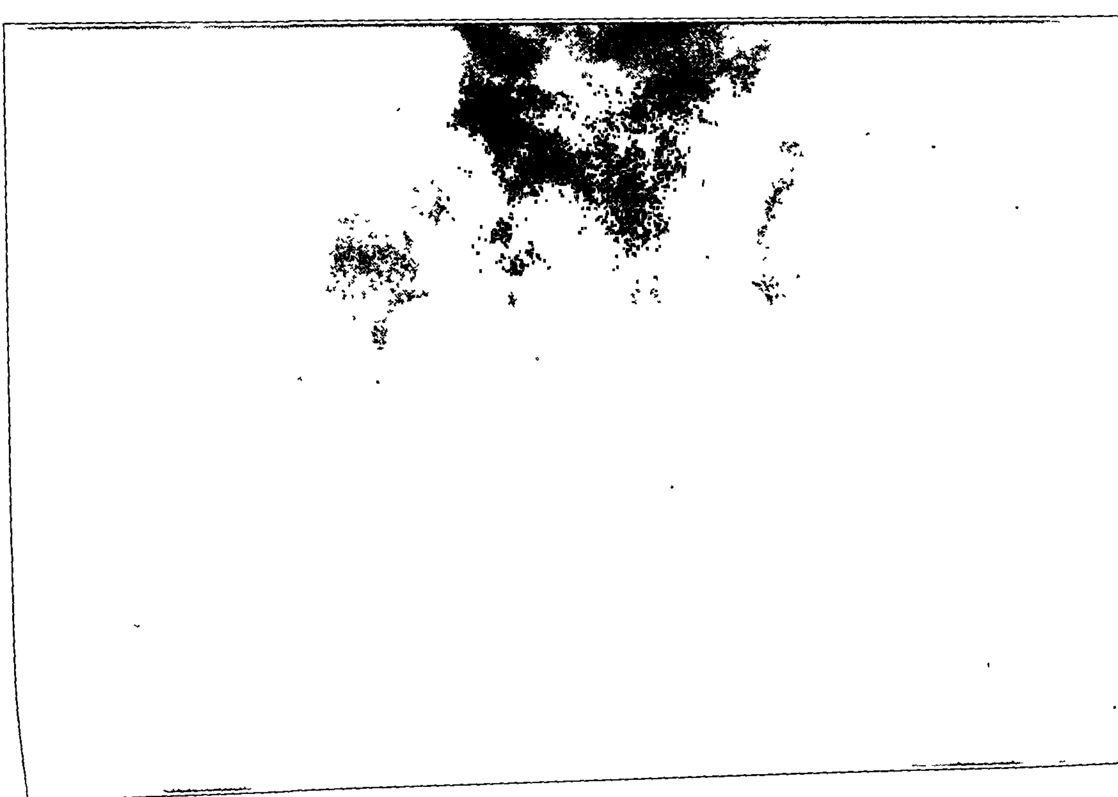

Fig. 1-A

Girl, seven months old. Roentgenogram does not clearly differentiate luxation from subluxation.

FIG. 5

FIG. 6

Fig. 5: New vertebral body, formed by the remnants of two affected vertebrae. This patient had tuberculosis of the spine, associated with tuberculosis of the lungs.
Fig. 6: Synosteosis of two vertebral bodies in a healed case of proved tuberculosis of the spine.

depended upon the ability of the involved spinal segment to obtain an approximation between the partially destroyed vertebral bodies.

Taking all these differences into consideration, we may summarize the formation of these blocks as follows:

When the destruction of the anterior walls of the infected bodies was not marked, the gap formed during the destructive stage was predominantly obliterated, either through telescoping or forward flexion, according to which one of the spinal segments was involved. Later on, a new vertebral body appeared, formed by the fusion of the vertebrae which had been partially destroyed. The new synosteosis had an anterior wall, sometimes only one-half or one-third the size of that of a normal vertebra (Figs. 5 and 6).

If the destruction of the anterior wall of both infected vertebral bodies had been far advanced or complete, the anterior involvement of several vertebral bodies situated above and below the primary infected vertebrae was frequently observed. The forward flexion of the upper spinal segment started during the early stages of the process. In the thoracic and thoracolumbar segments, the process continued unchecked until contact was made anteriorly between the upper articular surface of the more cephalically placed vertebral body and the lower articular surface of the body of the more caudally situated vertebra, thus producing the appearance of a triangle in the roentgenogram. As a rule, unless these patients were kept in recumbency for very long periods of time, the deformity increased, and two more contiguous vertebral bodies became involved. In the lumbar segment, the tendency toward forward flexion and kyphos formation was much less pronounced.

There were some exceptions to this general development. Some of the cases were similar to those described by Hellstadius under the name of "vesicular type" of tuberculous spondylitis; others were characterized by a slow and progressive destruction of the fourth lumbar vertebral body and intervertebral disc, with slight erosion of the upper articular surface of the fifth lumbar. In general, these cases followed more or less the pattern observed in the epiphyseal type of spondylitis.

In all of the cases of central spondylitis which healed by formation of a vertebral block, anterior ankylosis of the spine was obtained, while the patients were in recumbency. Follow-up from three to five years after the clinical healing of the process showed no

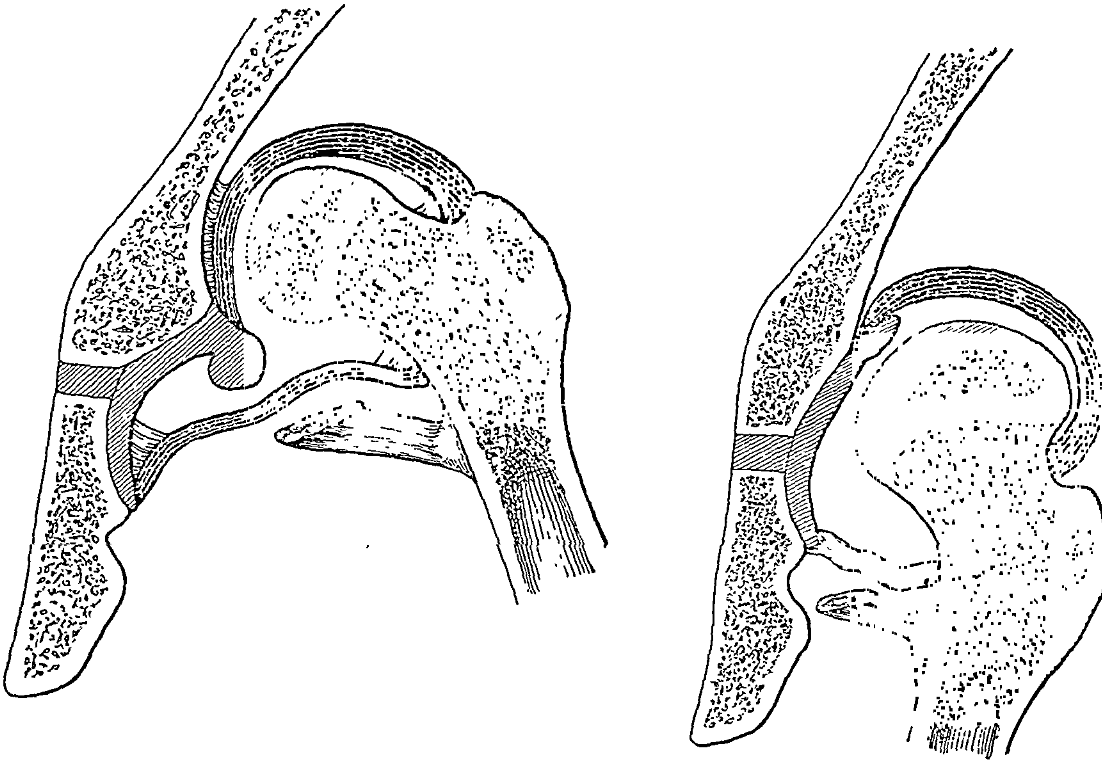

FIG. 2-A FIG. 2-B

Diagrams showing the essential differences between luxation and subluxation.

It is clear, therefore, that the interposition of soft parts (the limbus, the round ligament, and the lower fold of the capsule) is the rule in luxations, where it constitutes an obstacle to reduction. Such an interposition of soft parts never exists in subluxation.

The Neck of the Femur

In *subluxation* one often finds a valgus of the neck, the angle of which measures from

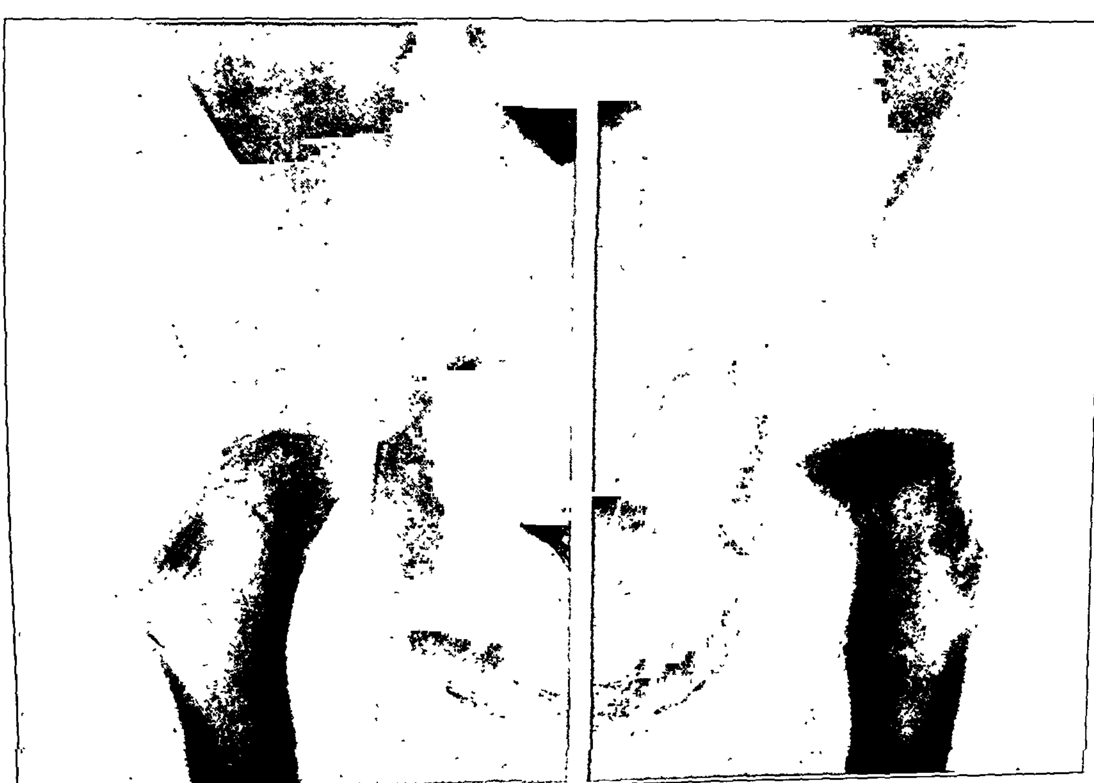

FIG. 3-A

Roentgenogram of a girl, twenty-one months old.

for periods of from three to five years, fused, and allowed to get up with a body cast three or four months after fusion, but before a sound vertebral block of the anterior spine had been obtained, the surgical fusion did not:

a. Produce the formation of a sound block;
b. Prevent further flexion of the spine;
c. Prevent the appearance of pathological fractures;
d. Prevent the spreading of the process to the surrounding vertebrae;
e. Prevent the appearance of new abscesses;
f. Prevent the appearance of neurological complications.

2. On the other hand, in the patients not allowed to get up until after a sound block had been obtained by conservative means, no signs of reactivation or collapse have been observed, whether or not fusion had been performed.

In the presence of these findings, it would be erroneous to conclude that the posterior fusion of the spine is of no value in the treatment of tuberculous spondylitis. This could be accepted, if a vertebral block could be obtained in every case of central tuberculous spondylitis. Unfortunately, due to the extension of the process, to its intensity, or to some peculiarities of the involved spinal segment, in some cases, an anterior synosteosis of the anterior spine does not take place, in spite of the use of very prolonged periods of recumbency. This occurs frequently in children, and in these cases the fusion of the posterior spine, while not ensuring against further increase of the process or of the deformity, increases the stability of a vertebral column, weakened by the process, by the "inflexion", and by the local subluxations.

In short, a sound vertebral block should be obtained every time that it is possible, even if it means prolonging the recumbency period; because it ensures a better prognosis, as far as the future stability of the spine and the healing of the process are concerned.

TUBERCULOUS SPONDYLITIS IN CHILDREN

While the general mechanism of block formation in children is similar to that observed in adults, the study of this series of cases revealed some peculiarities that warrant a further description.

In the first place, the division between epiphyseal and central types was not as definite; and, due probably to the size of the vertebral bodies, it was not infrequent to observe cases in which a primary epiphyseal infection extended far inside the vertebral body. Second, it was much more common to observe involvement of several contiguous vertebral bodies. Third, the number of cases in which a block could not be obtained was much higher in children than in adults. With the exception of two cases, no sound vertebral blocks were observed, if the tuberculous process involved more than five vertebral bodies. Fourth, in cases with localization to two or three vertebral bodies, the configuration of the block sometimes improved during the growing period.

The series of cases studied included twenty-one spondylitic foci in children, each of which healed by the formation of a vertebral block. These twenty-one cases were compared with several others of a similar type, in which no vertebral synosteosis had been obtained during recumbency.

Six of the cases that healed by formation of a block were cases of tuberculosis, proved by guinea-pig inoculation. Those remaining had a proved tuberculosis of some other part of the body. All were cases of spondylitis without sinuses.

In each of four cases, the process was confined to two vertebral bodies. Under conservative treatment, osseous synosteosis was obtained three years following the onset of the clinical symptoms. Observation, from three to seven years after clinical healing of the process had been obtained, showed no reactivation of the process or further collapse of the spine.

of his cases). This anteversion exists even in very young patients. It is therefore very early, if not primary. The degree of this anteversion undergoes practically no change in the course of life.

In *luxation*, on the contrary, there is no valgus of the neck. The anteversion is found only exceptionally in young subjects. In the course of life it increases progressively, and may reach a high degree in elderly subjects suffering from high luxation. In luxation, therefore, the anteversion seems to be secondary and late.

All these anatomical differences between subluxation and luxation are tabulated (Table I). They are easy to recognize and exist in the majority of cases.

In the course of our surgical experience, which is already considerable since it is based upon over 250 cases of luxation and subluxation, we have observed not more than two cases which may be exceptions to the rule,—that is, cases in which characteristics of both luxation and subluxation were found together.

It follows from my studies, therefore, that subluxation and luxation represent different malformations.

Developmentally it can be seen that, in luxation, the head may, in time, rise higher. My arthrographic studies have established that the proportion of high heads with narrow hourglass capsular constrictions increases with age, but we are still within the domain of luxation.

In subluxation, on the other hand, one may see the acetabulum wear down gradually or the head become deformed to a maximum degree, but the subluxation remains always a subluxation. In our opinion, not one well-established fact can prove that a subluxation, showing the characteristics which have been described, can become a luxation. Moreover, it is inconceivable that the limbus, forced upward and atrophied, as it is in a subluxation,

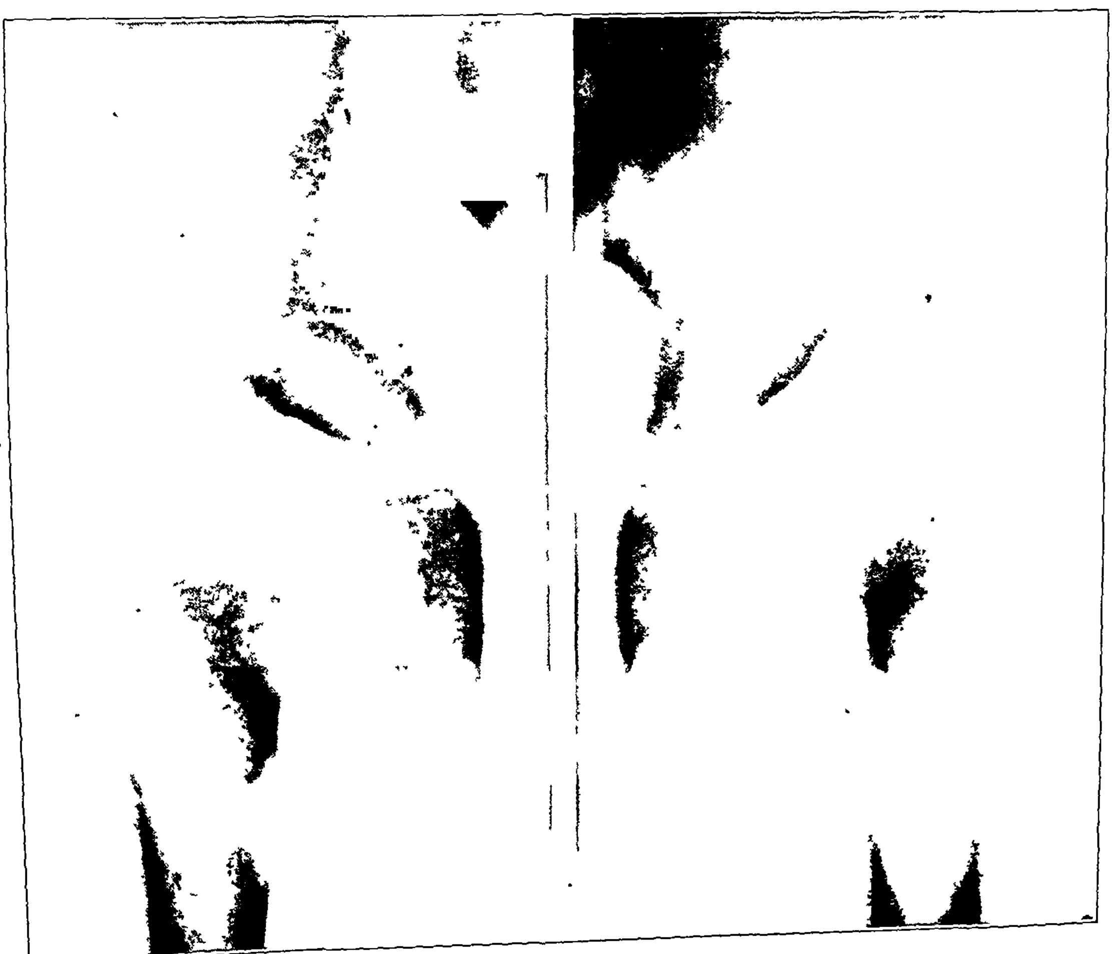

Fig 4-A

Roentgenogram of a girl, seventeen months old, showing subluxation on the left side.

vertebral bodies were markedly crushed and destroyed. The process of collapse of the spine continued as a rule until the two most distally placed vertebral bodies established partial contact at the level of their anterior parts.

In five of this group of twelve cases, spine fusions were performed after the children had been in recumbency for five or six years, at which time an anterior vertebral block was already present. In six other cases, in which also vertebral blocks had been obtained by prolonged recumbency, no surgical intervention was performed. The remaining patient was treated by recumbency during only one year; fusion was done; and the child was allowed to get up five months later in a body cast. Roentgenographic check-up for several years showed this to be the only one of this series in which no block had been obtained, and in which the deformity continued to be progressive.

When the tuberculous process had affected more than five contiguous vertebral bodies, *sound* blocks were observed in only two cases. In both cases, the process had affected the whole lumbar spine and the last two thoracic vertebrae. Under conservative treatment, synosteoses, including all the diseased vertebrae, were produced.

In the other cases, no blocks could be observed. For comparative purposes, the progress of these cases for several years was observed. All had been under periods of conservative treatment for four or five years. In practically all cases, in spite of the use of hyperextension and traction, the deformity increased and the process continued to progress for several years. Later, after spine fusions, these patients were allowed to get up, and invariably the spine deformity became more accentuated.

Whether or not this marked destruction and deformity could have been prevented, either by combining fusion and recumbency or by performing a very early fusion of the spine, cannot be stated. However, it is at present our conclusion that the surgical fusion of the posterior spine is not capable of preventing an increase of the deformity when the anterior spine is mechanically unsound, because of the presence of gaps, marked destruction, or decrease of resistance of the vertebral bodies.

CONCLUSIONS

The effects of a given treatment upon the evolution of a tuberculous spondylitis cannot be properly evaluated, unless the different topographical types of tuberculous spondylitis the number of infected vertebrae, the pathomechanics of the different spinal segments, and the alterations in the structure of the vertebral body produced by the infection are taken into consideration. Only after careful consideration of all these factors, is it possible to understand why in some cases sound healing may take place in one and a half to two years after the onset of symptoms, while in other cases the process continues to progress for longer periods of time.

NOTE: In regard to the incidence of formation of a vertebral synosteosis in cases of tuberculous spondylitis, no accurate percentage could be obtained from our material. This is due to the fact that we never considered suitable for purposes of *clinical investigation* those cases that, although clinically and roentgenographically typical of tuberculous spondylitis, did not fulfill the above described basic requirements. To state that those discarded cases were not tuberculous would be against the best clinical and roentgenographic judgment; to accept them as cases of tuberculosis would be against scientific accuracy We considered this last point far more important than any other, and consequently renounced all statistical investigations.

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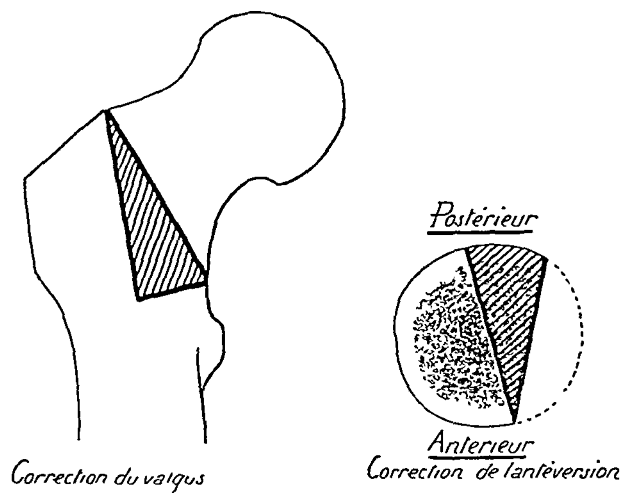

Fig. 5

Diagrams showing the Zahradníček method of correction of valgus and anteversion of the neck of the femur.

might in time become the limbus forced down toward the acetabulum and hypertrophied, as is seen in luxation. Still more is it inconceivable that the round ligament, which is absent in subluxation where the displacement of the head is very small, might reappear hypertrophied in a large number of luxations, even high luxations.

Without doubt subluxation and luxation have their origins in a common ground, since both malformations may coexist in one subject or may appear alternately in the course of hereditary transmission of the disease. However, both malformations originate at a stage of the embryonic development which it is impossible for us to determine, and under the influence of causes which are totally unknown to us. I can state, nevertheless, that from the initial stage, subluxation and luxation develop individually toward essentially different anatomical conditions.

CONCLUSIONS AS TO TREATMENT

The anatomical facts just described give an accurate idea of the difficulties which ill confront the surgeon when dealing with a congenital subluxation of the hip,—that is, hen he attempts to reconstruct a hip so that *the articular surfaces will be perfectly congruent.*

To achieve this condition is, in our opinion, the only way to prevent the appearance of a deforming osteo-arthritis, which is the almost inevitable consequence of an articular dislocation, imperfectly reduced.

I. *Closed Reduction*

The bloodless reduction must be checked rigorously by arthrography, which is done with a solution of *ténébryl* in a concentration of 30 per cent. This contrasting substance, dentical with that used in urography, is rapidly eliminated—in about thirty minutes—vithout affecting the articulation. There is no need to emphasize the fact that only by rthrography can one visualize roentgenographically the state of the soft parts (cartilage f the roof, limbus, and capsule), of which hitherto one would have no idea.

The tests for a perfect reduction are the same as those indicated by Faber for a ormal articulation:

(*a*) The tip of the limbus must come down in contact with a straight line drawn between the Y-shaped cartilage.

(*b*) The free edge of the cotyloid fibrocartilage must clasp a good half of the head.

(*c*) There must be no accumulation of the contrasting substance between the head and the center of the acetabulum.

In my experience the above conditions can only be fulfilled in very young children, less than two years of age, and even then, not in all cases. (This is the age at which we exceptionally see congenital subluxation of the hip.)

Experience has also shown us that the first Lorenz position gives a far better reduction than the position in abduction recommended by Putti.

Every time we left unchanged a manipulative reduction which the arthrograms showed to be unsatisfactory (the tip of the roof insufficiently lowered, the head incompletely clasped by the cotyloid fibrocartilage, and some contrasting substance remaining

PRIMARY CONGENITAL SUBLUXATION OF THE HIP *

BY PROFESSOR JACQUES LEVEUF, PARIS, FRANCE

In cases of congenital dislocation of the hip, Frenchmen, contrary to Anglo-Saxon authors, distinguish between luxation and subluxation. In the latter, according to recognized authorities, the head of the displaced femur remains in contact with a more or less deformed acetabulum.

The importance of this distinction is even greater than was formerly thought. My studies have shown that the primary subluxation of the hip presents some anatomical characteristics distinctly different from those of luxation. The use of arthrography, as practised by me since 1935, enables one to distinguish a subluxation from a luxation, without difficulty and even in the youngest child.

As pointed out by Gourdon as early as 1906, subluxation, thus defined, is a relatively stable condition which never tends to develop into a luxation.

The prognosis of this primary subluxation remains grave for a long time in most cases, because experience has shown that the results of closed reduction of subluxation, even in a young patient, are very seldom satisfactory. However, the reduction of the displacement—that is, the lowering of the head into the acetabulum—presents no difficulty in such a case. In spite of orthopaedic treatment, the articulation remains incongruent and, sooner or later, there appear signs of a deforming osteo-arthritis, which eventually becomes permanently disabling. The treatment of an established osteo-arthritis raises considerable controversy; all one can say is that surgeons have not yet discovered the means of effecting a real cure. In my opinion, the problem is the prevention of the deforming osteo-arthritis consequent to the subluxation of the hip. That is the principal subject of the present article.

At the start, I would specify that I am considering here only the primary congenital subluxation. The so-called "residual" subluxations, which are frequently observed after ... ted bloodless reduction of true luxation of the hip, are quite different. They are characterized, in particular, by the presence of interposed soft parts (limbus, round ligament, and capsule) between the head and the acetabulum; such interposition never occurs in primary subluxation.

DIFFERENCES BETWEEN SUBLUXATION AND LUXATION

These differences have been established with the help of arthrography, and the findings have been verified in the course of open reduction by the intra-articular approach.

The essential difference between these two varieties of malformation is indicated by the position of the cartilaginous roof, formed by the union of the non-ossified part of the acetabular rim with the cotyloid fibrocartilage (also called the limbus). *In a subluxation the limbus is forced upward and inward toward the iliac fossa; in a luxation the limbus is forced downward and inward toward the acetabulum.*

Such a distinction is clearly seen in Figures 1-A, 1-B, and 1-C (this patient was selected from a number of different cases). In this girl, aged seven and one-half months, the ordinary roentgenogram does not show any difference between the dislocation of the hip on the right side and that on the left side. Arthrograms, on the contrary, prove that on the right side there exists a subluxation with forcing of the limbus toward the iliac fossa. On the left side, there is a luxation with forcing of the limbus toward the acetabulum, which gives the articular cavity the classic hourglass appearance.

There are, however, a whole series of other anatomical differences between subluxation

* Read at the Annual Meeting of The British Orthopaedic Association, in London, October 26, 19

II. *Construction of an Artificial Roof*

This purely palliative operation seems to us completely illogical. It fails to correct the articular incongruity. In addition, as Wiberg reported in two cases, a deforming arthritis of the head may develop in spite of a perfectly successful artificial roof.

III. *Open Reduction*

This is the only means left to reconstitute good articular congruity in most subluxations. The most favorable age for this operation is around three years. The operation can be performed on older subjects (fifteen years and over) provided that the components of the articulation have not been deformed, especially by untimely orthopaedic manipulation.

FIG. 7-A

FIG 7-B

Figs. 7-A and 7-B: Arthrograms of a girl, two years old, showing insufficient reduction of subluxation of the left hip (May 1946).

In *luxation*, on the other hand, the head retains a regular contour for a long time. As regards its volume, the head appears slightly smaller than normal in the majority of cases.

The Articular Capsule

In *subluxation* the capsule, although enlarged, is never interposed between the femoral head and the acetabulum. What is more, intra-articular operations have shown that the round ligament is practically always absent.

In *luxation*, on the other hand, the capsule often is interposed between the head and the acetabulum, especially at the lower portion of the cavity. The round ligament is present in about one third of the cases It is often so big as to constitute an obstacle to reduction The hypertrophied round ligament is always visible on arthrograms

Fig. 1-B

Arthrograms show subluxation of the right hip and luxation of the left Note the difference in the shape of the head in luxation and subluxation

Fig 1-C

After closed reduction, all the tests of a good reduction are present. Note that the tip of the roof reaches the Y line.

TABLE I

DIFFERENCES BETWEEN SUBLUXATION AND DISLOCATION

	Subluxation	Dislocation
Limbus and cartilaginous roof	Pushed upward against the ilium Atrophied	Pushed downward into the acetabulum Hypertrophied
Acetabulum	Early becomes oval in shape because of atrophy of roof	Normal Entrance restricted by displaced glenoidal labrum
Femoral head	Hypertrophied Enlarged transversely	Normal or atrophied
Capsule	Never interposed	Frequently interposed
Ligamentum teres	Absent	Present in 33 per cent. Often hypertrophied
Valgus	Developed early, if not primary	Developed late and secondary
Anteversion	Developed early, if not primary	Developed late and secondary

Zahradníček's method. The two osseous fragments of the neck are then fastened with a nail, triangular in section.

5. At the end of the operation, the capsule is sutured only at its upper part, after all the extruding parts have been resected.

The limb is then put in plaster, in a position of slight abduction and internal rotation, nd is held in this position for a month. At the end of the month, exercises are begun. The atient gets up in the third month. During convalescence, great care must be taken that he articulation retains a correct position. If there is a tendency to flexion, adduction, or xternal rotation, this will be corrected by usual orthopaedic methods.

The mortality resulting from this rather delicate operation has been nil. I have to ate performed consecutively more than 250 open operations in cases of subluxation or ıxation of the hip (the technique being analogous) without losing a single patient. Such ood results are due, not only to the perfection of the technique, but also to the use of a reventive treatment for postoperative shock (intravenous perfusion of physiological saline ith the addition of adrenalin as needed).

No postoperative osteochondritis has een observed. After trapezoidal resection f the neck, the seemingly threatening dan-

FIG. 8-A

FIG. 8-B

Fig. 8-A: Roentgenogram (Feb. 1937) of a girl, twelve years old, showing subluxation of the left hip.
Fig. 8-B: Apr. 1937. Following reduction by the intra-articular method (with resection of the neck).

150 to 155 degrees, whereas on the sound side the angle measures 130 degrees. The presence of the valgus of the neck is indicated in the observations of the various authors, such as Klapp and Waldenström, who have described "coxa valga luxans". The anteversion of the femur, measured as exactly as possible by the methods of Perry Rogers, of Dreesmann, and of Netter, is very common in subluxations (the author has found it in 68 per cent.

FIG 3-B FIG. 3-C

Bilateral subluxation, evident in the arthrograms.

FIG 3-D

Good result two years after closed reduction.

the congruity of the articulation, will safeguard these patients against deforming arthritis. Only the future can show whether the late results will fulfill that hope.

NOTE: The illustrations have been reproduced from the author's book, entitled "*Luxations et Subluxations Congénitales de la Hanche. Leur Traitement Basé sur l'Arthrographie*", by permission of Gaston Doin et C^ie^.

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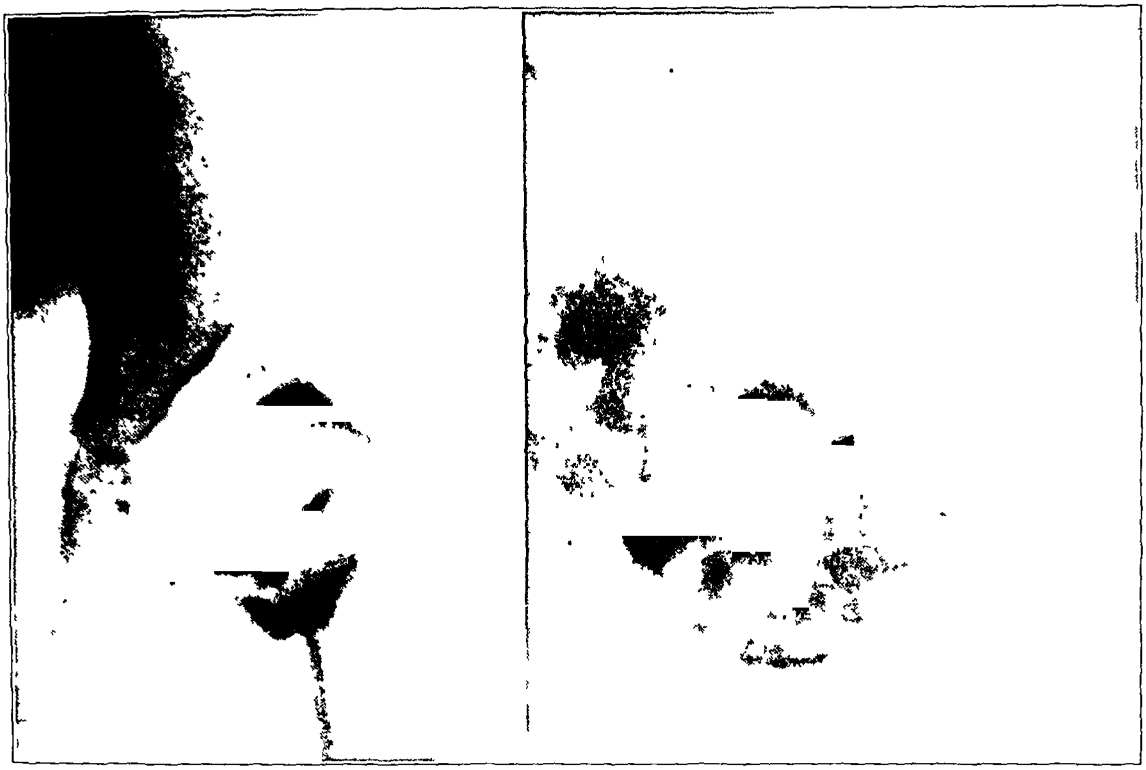

FIG 4-B

FIG. 4-C

Insufficient reduction, shown by arthrograms by the Lorenz method was continued. Nevertheless, the treatment for closed reduction

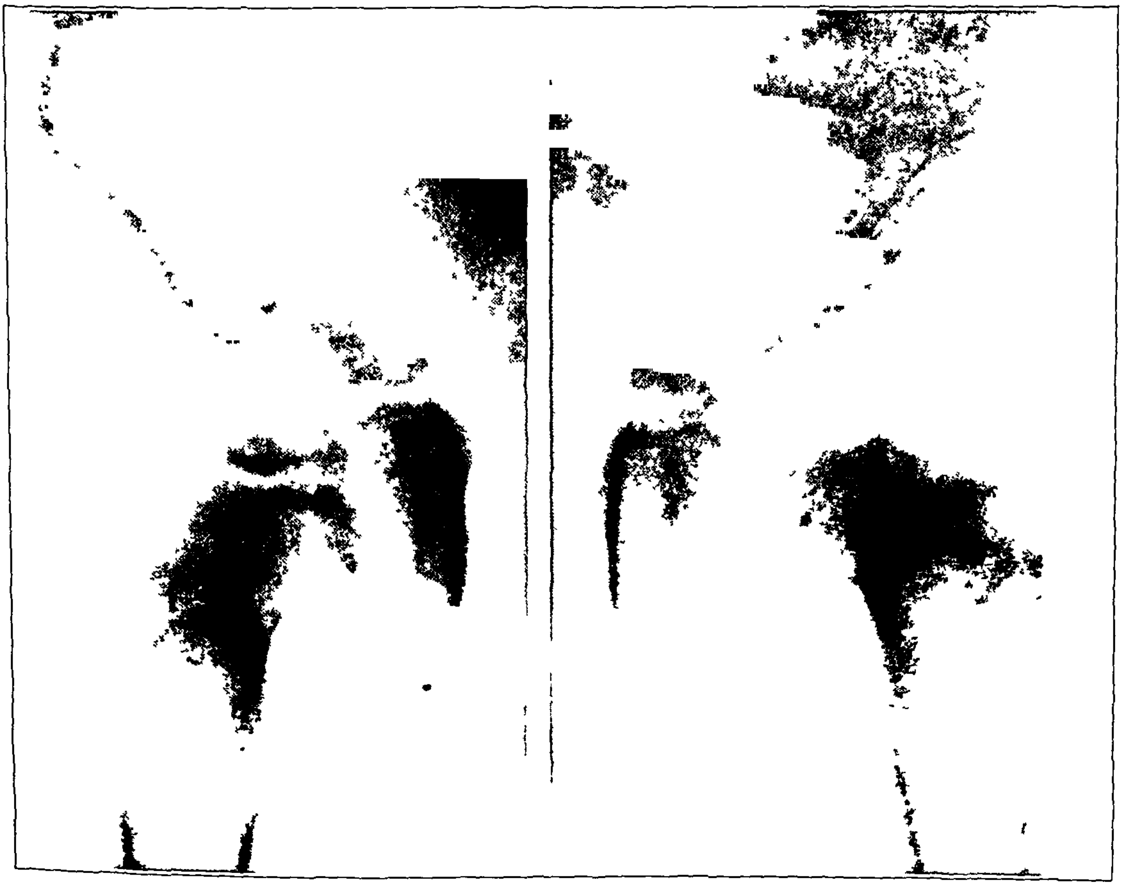

FIG. 4-D

Result after two years and eight months, showing poor reduction and osteochondritis of the head.

In each stage, the procedure consists in exposing only one side of the spinous processes and laminae. A bed for the tibial graft is made by turning down bone chips from the

FIG. 1

FIG. 2

Fig 1: Parallel grafts.
Fig. 2: Two-stage interlocking grafts. (The corrective jacket has just been removed and decompensation of the lumbar curve has not yet occurred.)

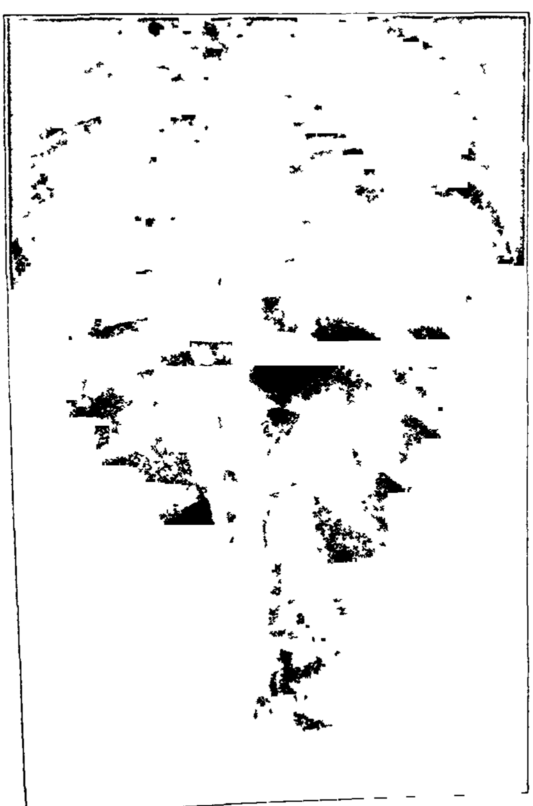

FIG. 3

FIG. 4

Fig. 3: Three-stage interlocking grafts (in a double primary curve).
Fig 4: Fracture of graft on left side, just above tenth rib.

between the head and the acetabulum), the results were bad. Not only was the reduction not effected, but in many cases there occurred an osteochondritis of the head which resulted in an even more serious deformity (Figs. 4-A, 4-B, 4-C, and 4-D).

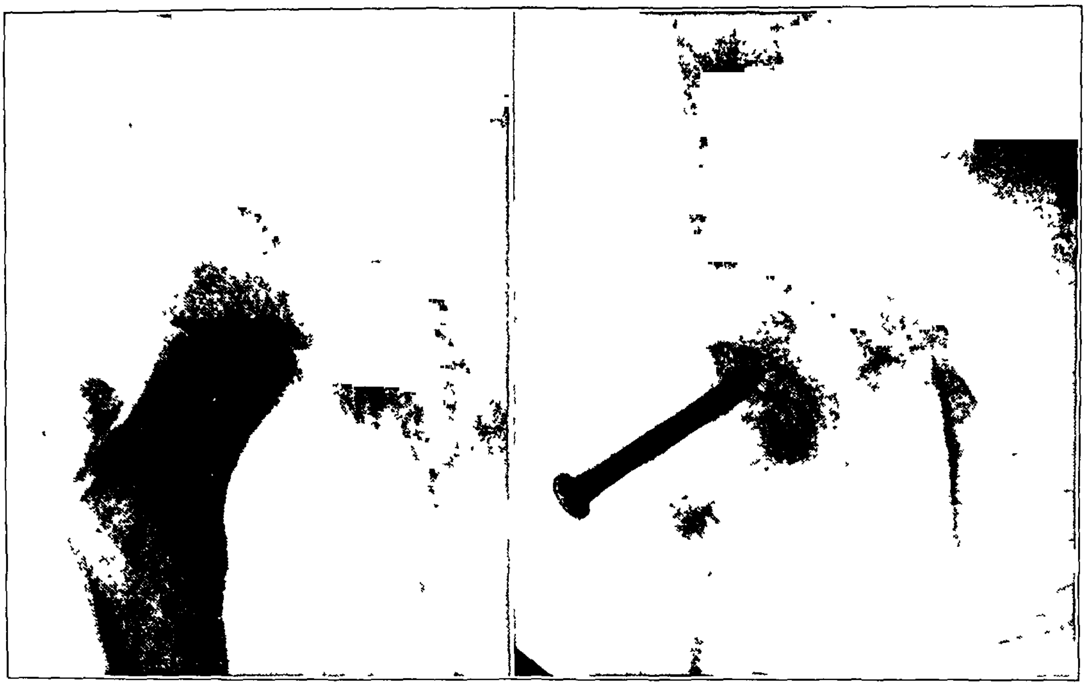

Fig. 6-A Fig. 6-B

Fig. 6-A: Roentgenogram (Nov. 1942) of a girl, seven years old, showing subluxation on the right side.
Fig. 6-B: Feb. 1943. After reduction by the extra-articular method.

Fig. 6-C
June 1946. Good result four years after the operation.

ing sinus developed which persisted, and roentgenograms showed aseptic necrosis of a portion of the graft. This fragment was removed, and, because of the interlocking technique used, with ample overlap of the grafts, no particular loss of correction occurred.

Fracture of Graft: In only three cases (7.3 per cent.) did fracture of a graft occur. In one patient a fracture developed at the end of the middle graft in a three-stage interlocking procedure, apparently before the third stage was done. Since there was sufficient overlap of the other graft, no undue loss of correction developed and no further surgery was necessary. In a second patient the fracture was found early, before there was much loss of correction, and a repair of the pseudarthrosis was carried out. The third patient has recently been re-admitted for surgery. In each instance the fractured graft was easily demonstrated by roentgenogram (Fig. 4). This represents an advantage of this operative procedure over the Hibbs technique, in which it is very difficult to make an early diagnosis of pseudarthrosis.

Fracture of Tibia: One patient fractured the tibia from which a graft had been removed.

Pressure Areas: Mild pressure areas developed in three cases.

Partial Brachial Palsy (Transient): Five patients (12.2 per cent.) had mild, transient, partial brachial palsy.

Wound Infection: There was one case of mild infection of a leg wound.

Double Primary Curves: Although not truly a complication, the double primary curve may well be considered here. If unrecognized, it can cause an unsatisfactory end result, even though the chosen primary curve has been well corrected and successfully fused (Figs. 5-A, 5-B, and 6).

The criteria used in selecting the primary curve[10] are generally known, and have proved of great value if there is a single primary curve. Unfortunately these rules do not apply to the double primary curve, and no certain method for detecting such a curve is at present available. Von Lackum's observations in this regard are of distinct help.

Fig. 6

Roentgenogram of a double primary curve. It was so labeled because the lumbar curve did not straighten in the tilt test, the thoracic curve was clinically rigid, and the vertebrae showed wedging and rotation.

If a patient with a double primary curve is discovered, several methods of treatment have been advocated:

1. The most deforming curve is corrected and, if the end result is unsatisfactory, the second curve is corrected and fused.

2. The thoracic curve is corrected, and then apparent balance of the involved pelvis and the prominent hip is induced through the use of a heel lift[5]. This is not too happy a solution, since the patient, after undergoing rather strenuous treatment, must still depend upon mechanical aid.

3. The thoracic curve is corrected as much as possible, then the lumbar curve is corrected to an equal amount, and fusion of the entire area is carried out.

This last procedure proved most successful in the five cases of double primary curves in this series. The correction with a Risser jacket is done by using two sets of hinges and two turnbuckles. First the thoracic curve is corrected; then the lumbar curve is straightened

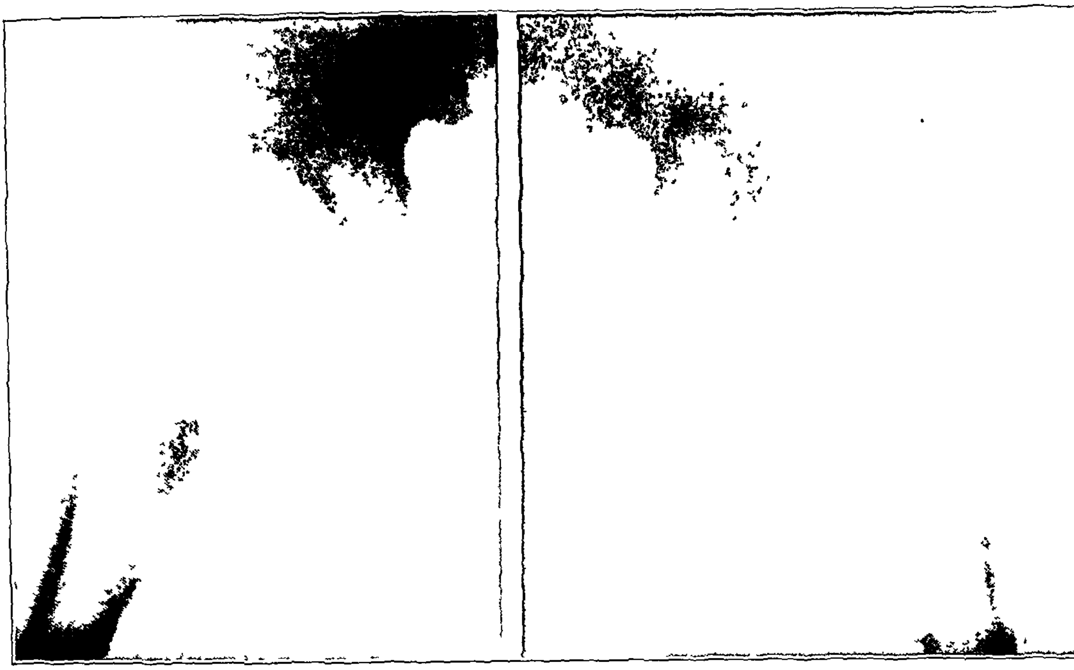

FIG. 7-C

Immediate result following open reduction by the intra-articular method, without resection of the neck (July 1946).

(*a*) *Open Reduction by the Extra-Articular Method*: For a long time I resorted to a technique based upon that of Zahradníček. This operation, which is entirely extra-articular, consists in lowering the head into the acetabulum by correcting the valgus and the anteversion through a wedge osteotomy at the base of the neck,—a wedge which has both a base distally to correct the valgus and a base posteriorly to correct the anteversion. The operation is concluded by lowering the osseous roof, which is held in place by a graft, taken from the fragments resected from the neck (Fig. 5).

This method, which I have used in fifteen cases, gave good reductions in only a few patients. In most cases there remains an abnormally wide gap between the head and the bottom of the acetabulum, the head being too big to penetrate the cavity. In these conditions a good articular congruency can only be obtained by some scraping out of the bottom of the acetabulum, especially in its lower segment. For this reason, I have now resorted to open reduction by the intra-articular approach.

(*b*) *Open Reduction by the Intra-Articular Approach*: This technique has been used by me in some thirty cases to date.

First, Ollier's transtrochanteric approach is used, which allows all necessary corrections to be made on the various elements of the articulation. After the trochanter major and the gluteus medius muscle have been raised, the capsule is cut circularly. The opening into the acetabulum is extremely large. The various moves in the operation are as follows:

1. Scoop out the acetabulum with a curette or gouge. This is done under most favorable conditions in young children, in whom the layer of cartilage covering the acetabulum is thicker.
2. Free the capsule from its adhesions to the external iliac fossa.
3. Lower the scooped roof by means of a slightly oblique osteotomy, reaching the cartilaginous covering of the acetabulum without cutting through it. The lowered roof will be held in place at the end of the operation by a graft taken either from the upper extremity of the femur, or from the wedge-shaped fragment resected from the base of the neck, when this resection has been made.
4. When accurate measurements have shown that there is a pronounced degree of valgus and anteversion, a trapezoid resection is made at the base of the neck, after

Although the Risser jacket was used in all but two cases to obtain correction of the curvature, in six cases the hammock suspension method of LeMesurier was tried. Four cases were classed as severe, one as moderate, and one as having a mild curve.

Of the severe curves, a 76-degree curve was corrected in the hammock to 70 degrees

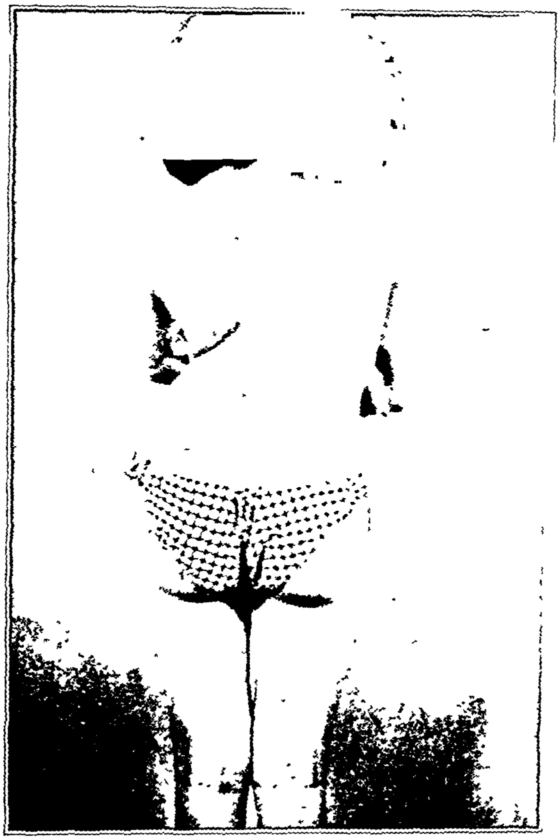

FIG. 7-A

FIG. 7-B

Fig. 7-A: This patient had a severe curve,—58 degrees before correction.
Fig. 7-B: At end result, only 13 degrees of correction was retained. The statistical result is poor, yet the clinical result is very acceptable.

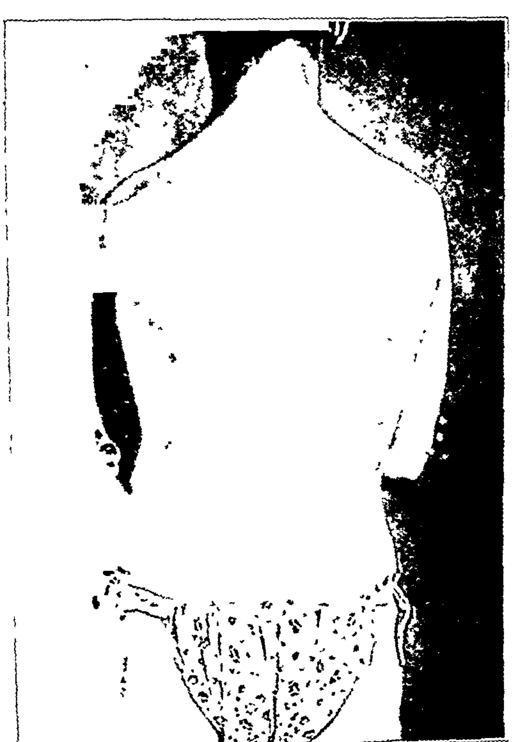

FIG. 8-A

FIG. 8-B

Photographs of a mild curve before correction and at end result.

FIG. 8-C

FIG. 8-D

Good result eight years after the operation.

ger of resorption of the head through insufficient vascularization is actually very small. I have observed only one case, in one of my first patients, when I had probably been too careless with the musculocapsular flap of the lower segment of the neck, through which a good circulation in the femoral head is easily maintained.

The anatomical results are always very satisfactory and well-nigh perfect, when all operative details have been followed. The functional results, especially the mobility of the joint, depend mostly upon the age of the patient and upon the extent to which the acetabulum has had to be scooped out. In young subjects the articulation always recovers normal, or near normal, mobility. In older patients some stiffness is observed, which, as a rule, is compatible with very satisfactory joint function. This stiffness tends to diminish with time.

At present, it is too early to say anything about late results, since my earliest operation by the intra-articular method was performed only eight years ago.

Figures 8-C and 8-D show the result of my earliest operation by this method, which is really encouraging. Results of this order are, of course, obtained more easily when operating upon young subjects, in whom resection of the base of the neck is unnecessary.

We have every reason to hope that this logical reconstructive surgery, which restores

of 26 degrees were corrected down to 2 degrees by this method, and these patients were placed in plaster jackets while suspended in the fish net.

SUMMARY

Significant improvement in the amount of correction retained and a substantial decrease in the incidence of pseudarthrosis have been achieved in forty-one cases of idiopathic scoliosis. These patients were treated by a modified technique of using tibial grafts in spine fusion, after obtaining maximum correction (by the Risser type of plaster jacket in thirty-nine cases and by the hammock suspension method in two cases).

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THE USE OF PARALLEL GRAFTS AND OF TWO-STAGE AND THREE-STAGE INTERLOCKING GRAFTS IN THE TREATMENT OF IDIOPATHIC SCOLIOSIS

End Results in Forty-One Cases

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In the past several years, the few articles published on the subject of severe or progressive idiopathic scoliosis have consisted chiefly of excellent reviews on the treatment of this condition[3,7,8,10]. The use of the Risser turnbuckle jacket to correct the predetermined primary curve, followed by spine fusion to maintain this correction, is the method advocated chiefly.

LeMesurier and Blount and Schmidt have sought to simplify the method of obtaining correction. LeMesurier has proposed a hammock suspension cast, which is said to secure as much correction as the hinged jacket in an easier and less time-consuming manner. Blount and Schmidt have devised a corrective brace which they believe supersedes the tedious and prolonged method of Risser.

Whatever the merits of these two methods may be, neither meets the greatest need. An analysis of the report of the Research Committee of The American Orthopaedic Association[9] suggests definitely that the chief problem is not an easier method of obtaining correction, since the average correction attained was 61 per cent.; but the need is rather for a better means of maintaining the correction, since the average correction at end result was only 25 per cent. An even greater need is for a method which will eliminate or minimize the high incidence of pseudarthrosis, which amounted to 28 per cent. in the Committee's report, and of delayed fusion. In cases of delayed fusion, the fusion occurs after most or all of the correction and balance have been lost. Recorrection can only be obtained after an osteotomy of the spine has been performed through the fused area.

By a modification in the technique of using tibial grafts in spine fusion, developed by the senior author, apparently significant improvement has been achieved in both of these directions, when the present results are compared with those previously obtained by the Hibbs method of spine fusion, as well as with those reported by the Research Committee.

PROCEDURE

The technique used in fusing the corrected portions of the spine was developed gradually in a series of steps. Early, with short curves which included only six or seven vertebrae, parallel tibial grafts were placed on either side of the spinous processes in two stages (Fig. 1). With this type of procedure it was hoped that, if fusion was not secured in a greater percentage of cases, it would at least be easier to detect a fractured graft than to demonstrate pseudarthrosis in a spine fusion, done by the use of multiple chip grafts. As a matter of fact, the first hope was realized more than the second; for, while the incidence of fractured grafts was very low, the grafts often fused so completely and rapidly with the host bone that they very early lost their identity.

In longer curves, where it was not possible to apply the tibial grafts in a parallel manner, they were spread apart to include the entire curve and were interlocked in the center, thus giving the maximum support at the point of greatest stress. These were termed two-stage interlocking grafts (Fig. 2). Finally, in long curves, it was decided to use three-stage interlocking grafts. This was accomplished by putting the first graft on one side of the spinous processes, the second graft on the other side, and the third graft on the original side (Fig. 3). Each graft overlapped a minimum of two vertebrae.

FIG. 1
Proximal epiphyseal cartilage of tibia of guinea pig, illustrating cytomorphosis of cartilage cells and growth of capillaries into spaces left by death of cells.

The substance of this lecture should be presented against a background, provided by n outline of normal bone growth and the effects thereon of vitamins C and D deficiencies.

Increase in size of most bones during growth of the skeleton—all those which are first laid down as hyaline cartilage in the embryo, including all of the long bones, the vertebrae, and bones of the base of the skull—is by endochondral bone formation for which purpose, until growth is completed, cartilage persists at epidiaphyseal junctions. Growth of a long bone, for example, is accomplished by continuous proliferation of cartilage cells, arranged in columns on the epiphyseal side, and concurrent degeneration of matured cartilage cells on the diaphyseal side. The spaces which result from the degeneration and disappearance of the cartilage cells at the diaphyseal ends of the columns are penetrated by capillaries, accompanied by osteoblasts, which are responsible for the deposition of bone matrix upon the exposed cartilage matrix. Multiplication, increase in size, maturation, and death of cartilage cells (cytomorphosis) [10] are, therefore, necessary sequences in normal skeletal growth [13] (Fig. 1).

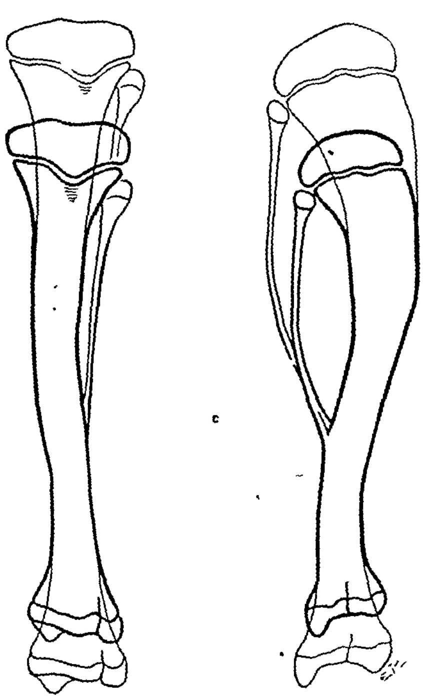

FIG. 2
Tibia and fibula of rat. Diagram to illustrate remodelling during growth, viewed from anterior aspect and in profile.

However, growth of bone is not a one-way process; preservation of conformation demands continuous remodelling, involving resorption of bone where reduction of size is necessary and new deposition of bone from endosteal and periosteal sources to preserve continuity of structure (Fig. 2). The deposition of bone by cells

spinous processes and laminae without attacking the lateral articulations. Then, with the graft in place, the spinous processes are undercut and, by the use of several Lembert sutures through the muscle and periosteum, the spinous processes are inverted to come into close contact with the graft.

In the more severe curves, particularly in patients with increased anteroposterior curves, it is necessary to secure curved tibial grafts. However, since the segments are relatively short in the two-stage and three-stage interlocking procedures, this is almost always possible to accomplish. In the few cases in which it is not possible, equal difficulty would be encountered in doing the classical Hibbs procedure, since the convex side of the vertebral curve is almost inaccessible, as the laminae and facets are rotated, twisted, and overhung by the spinous processes and the distorted convexity of the ribs. The procedure of Henry and Geist is usually followed in these severe cases.

The necessity for two incisions, one of which results in a scar on the leg—especially for a condition in which the chief purpose of correction is cosmetic—is admittedly a distinct disadvantage. Nevertheless, the advantages of this method of spine fusion outweigh the disadvantages. The procedure produces less shock, because only one side is exposed and dissection need not be carried out to the lateral articulations, which are often inaccessible in severe curves; the incidence of pseudarthrosis is greatly decreased; and the percentage of correction maintained as an end result is significantly increased.

COMPLICATIONS

Mortality: In this series of forty-one cases of idiopathic scoliosis treated by jacket correction and spine fusion (which included ninety-one operative procedures), there was a mortality rate of 0 per cent.

Aseptic Necrosis of Graft: In one case (2.4 per cent.), after primary healing, a drain-

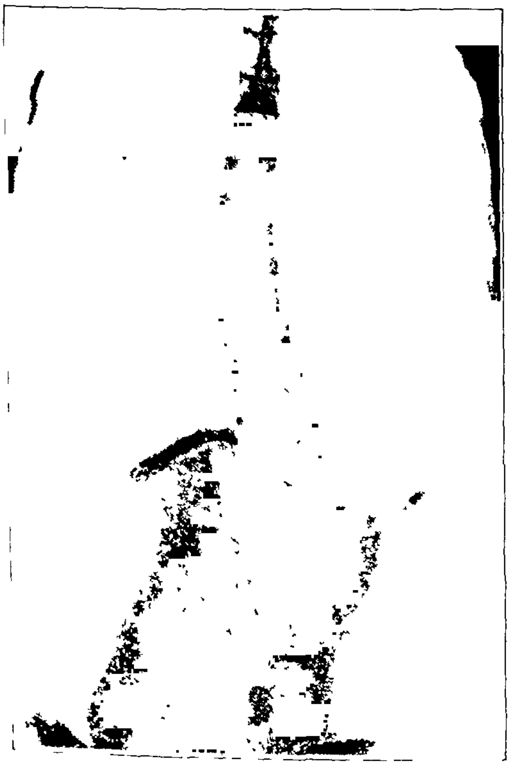

Fig. 5-A

Fig. 5-B

Fig. 5-A: Film, taken before treatment, shows curve from eleventh thoracic to third lumbar vertebra. This was selected as the primary curve, because it is the middle curve, it is the greatest curve, and the vertebrae are most rotated.

Fig. 5-B: Shows end result. In spite of correction of the curve from 37 degrees to 8 degrees, decompensation of the thoracic curve did not occur, indicating that this is also a primary curve.

VITAMIN-D DEFICIENCY

Normal growth of bone in the human is dependent upon the action of vitamin D in maintaining efficient concentrations of calcium and phosphorus ions in the blood plasma. In the rat, normal bone growth in the absence of vitamin D continues, unless the diet is such as to produce in the blood a "relative deficiency of calcium or phosphorus or an absolute deficiency of either or both" [13].

It is not necessary to present the pathology of rickets in detail, because this would lead into controversial fields, some of which would not exist if more attention had been given to early recovery sequences in cure of experimental rickets. Experimental rickets in rats reproduces accurately the spontaneous disease in human infants and other animals. As in all deficiencies, an understanding is to be sought in terms of retardation or suppression of normal processes, in this instance growth sequences in epiphyseal cartilage and of calcification of bone and cartilage. The reason why the pathology of human rickets is apparently so complicated is that the deficiency in any individual studied may have been intermittent or of varying degrees from slight retardation to almost complete suppression. Endochondral growth of bone is dependent upon proliferation, differentiation, and degeneration, ending in death and disappearance of cartilage cells [17]. In rickets the cartilage cells fail to complete this sequence; they reach their maximum size, produce adequate amounts of matrix, but do not degenerate. For this reason, as proliferation continues, the epiphyseal cartilage accumulates. In the absence of spaces created by the disappearance of cartilage cells, there is no ingrowth of capillaries. Concurrently with the arrestment of cartilage-cell sequences, the matrix adjacent to the persistent cells fails to calcify. Absolute rickets in the sense of the complete cessation of the above sequences is of doubtful occurrence in humans and difficult of experimental achievement. The arrestment takes place irregularly across the diaphyseal face of the cartilage plate. Wherever cartilage cells degenerate, vascular ingrowth takes place, in normal direction or laterally as opportunity offers; but the bone matrix (osteoid) deposited about the capillaries does not calcify.

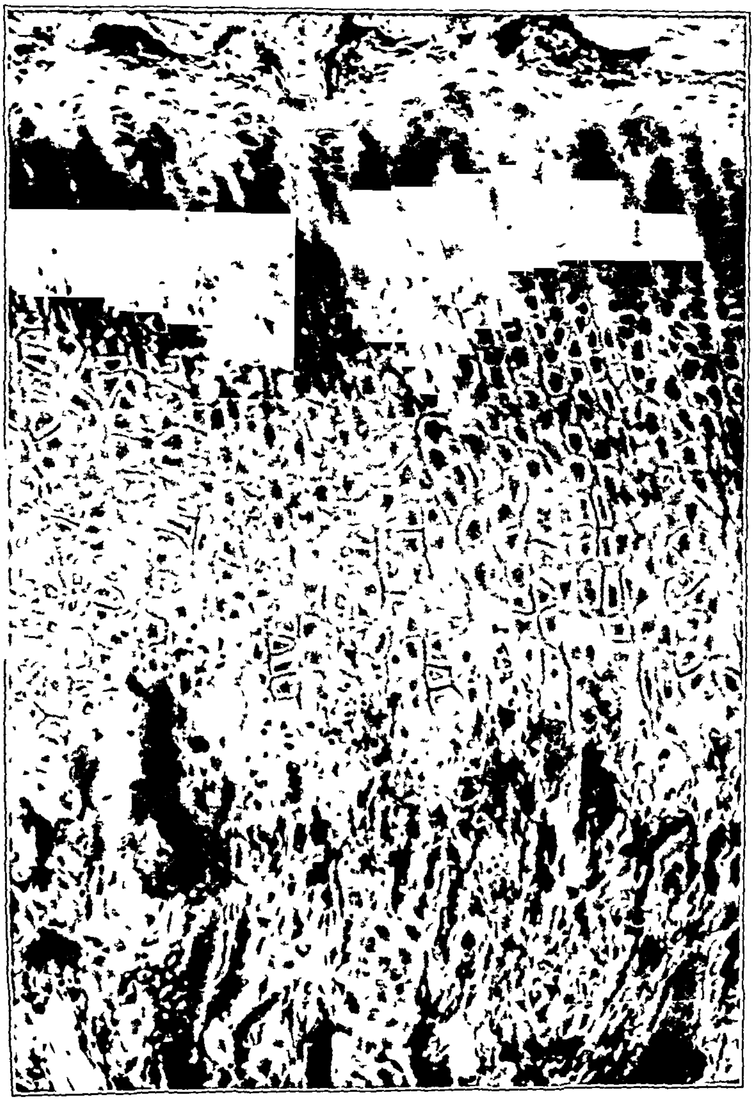

FIG. 4

Proximal epiphysis of tibia of rat. Showing repair of experimental rickets after seventy-two hours, and illustrating resumption of cytomorphosis.

Deposition of bone matrix (osteoid) continues to take place around capillaries of the

TABLE I

AVERAGE PERCENTAGE OF CORRECTION FOR EACH CURVE

Type of Curve	Report of Research Committee			Present Series		
	No. of Cases	Correction after Operation (*Per Cent.*)	End Result (*Per Cent.*)	No. of Cases	Correction after Operation (*Per Cent.*)	End Result (*Per Cent.*)
Mild (0 to 24 degrees)	10	71	33	1	94.0	80.0
Moderate (25 to 44 degrees)	51	72	25	11	71.5	49.6
Severe (45 degrees and over)	88	53	24	24	57.3	40.0
	149	61	25	36	62.6	43.1

equally. This method obviates the necessity of applying two corrective jackets, and materially shortens the time of treatment. Finally, the entire area is fused by using the necessary number of interlocking tibial grafts (Fig. 3).

END RESULTS

Table I shows that the end results in this series of cases of idiopathic scoliosis are substantially improved over the results indicated by the Research Committee. These patients have, for the most part, been followed for from two to five years, and the shortest follow-up period is well over a year after operation. Successive roentgenograms indicate that no gradual loss of correction is occurring.

Since corrective treatment is undertaken with the idea of eliminating or decreasing the degree of curvature, the success or failure of the method must be judged on this basis. However, the cosmetic end result is more directly related to the restoration of body balance than it is to the number of degrees of correction (Figs. 7-A and 7-B).

The preoperative and end-result photographs of approximately average cases (mild, moderate, and severe) are shown in Figures 8-A, 8-B, 9-A, 9-B, 10-A, and 10-B.

An analysis of the end results in this series indicates that over half the cases treated are classified as severe. A definite cause of this is the practice of treating early cases of idiopathic scoliosis with casts and braces for long periods of time, without adequate roentgenographic follow-up. Forty-nine per cent. of these cases were so treated early in the disease, and in all progression continued.

In treating scoliosis with the types of braces commonly used, one attempts to correct the spine indirectly through pressure on the thorax, which is an elastic structure; and thus a great deal of the force exerted will be spent merely on increasing the angulation of the ribs or changing the relations at their costovertebral joints[1]. At best, the method is of questionable value. If it is used at all, it certainly should not be persisted in to the point of allowing a mild curve to progress to the moderate or severe stage.

The most satisfactory early approach to the problem is a careful check on the progress of the curve by direct measurements of roentgenograms taken every three months. Postural exercises are often used during these intervals. Curves that show progression should be considered for correction by the Risser jacket and spine fusion, always remembering that some curves will progress, but finally become arrested before they reach a degree which is clinically important.

Although it is the authors' chief purpose to present *operative procedures* and end results in the treatment of idiopathic scoliosis, a brief discussion regarding the methods of obtaining correction seems within the scope of this paper.

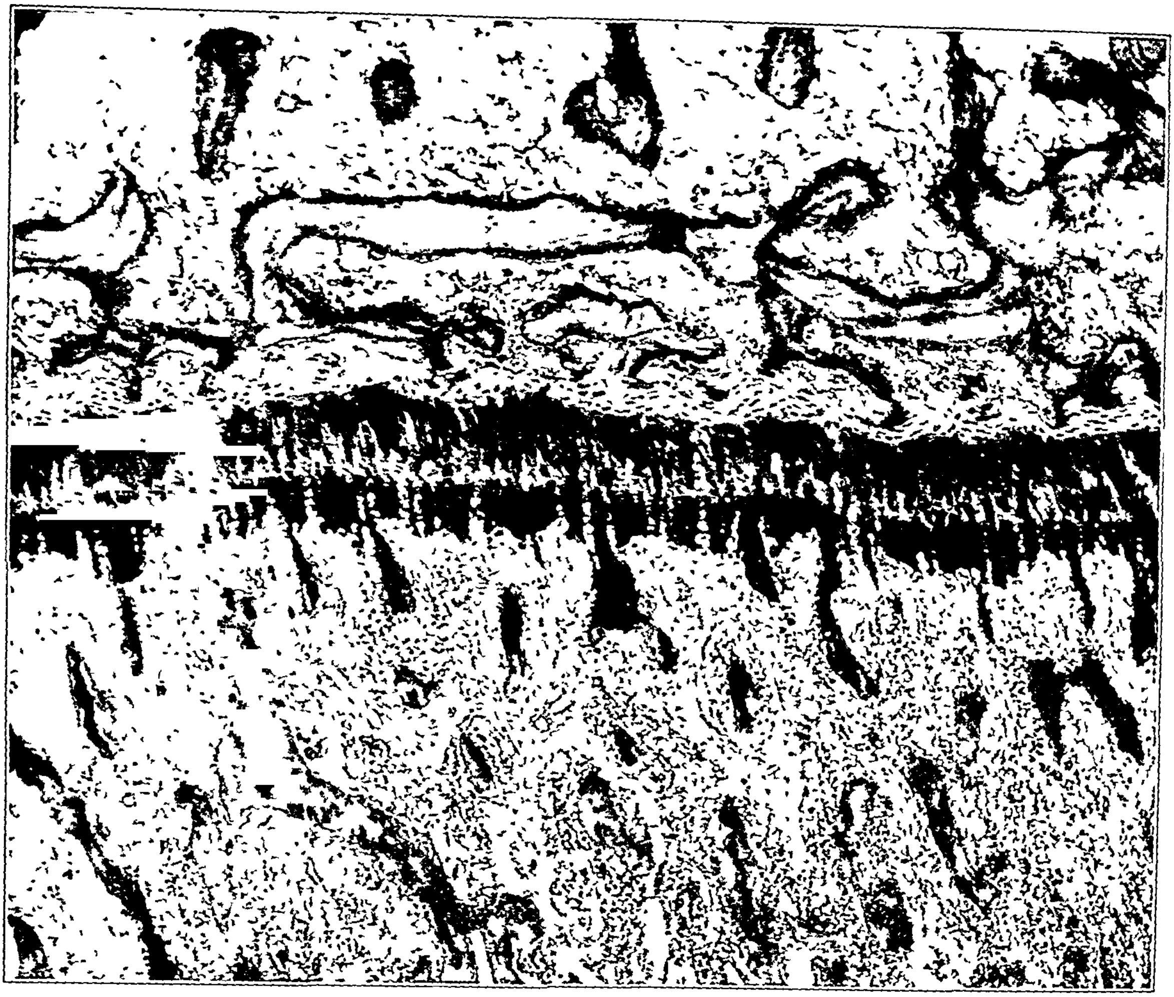

FIG 6
Proximal epiphysis of tibia of vitamin-A deficient puppy of the same litter as source of Fig 5

cartilage cells to complete the sequences of proliferation, maturation, and degeneration, the other the failure of matrices to calcify.

A comment made some years ago in regard to experimental rickets and which applies also to osteomalacia is perhaps worth repeating: "The degree or severity of rickets may be estimated and recorded on the basis of the prominence of anatomical changes demonstrable by roentgenograms or histological study. Obviously two factors enter into the production of the pathological picture, the duration of the deficiency and the degree of the deficiency as measured by calcium and phosphorus blood concentrations and ratios. Either factor can be made the variable and thus the time factor can be calibrated against the chemical factor — in so far as increased width of epiphyseal cartilage and accumulation of osteoid are concerned" [17].

HYPERVITAMINOSIS D

The administration of excessive amounts of vitamin D (activated ergosterol) produces untoward effects in bone and soft tissues, resulting from a great increase in serum calcium [1]. The physiological role of vitamin D is still generally regarded as one operative in the process of absorption of calcium from the intestines. The fact that, if the alimentary source of calcium is not adequate, calcium is obtained through resorption of bone [6,12] suggests that a more important role is to be found in the establishment of equilibrium conditions in the blood plasma. The stoichiometry of blood calcium seems to have quantitative relations with the amount of vitamin D introduced. The maintenance of high calcium levels in rats through its use results in short bones with non-calcified trabeculae of unusual thickness and number at the epiphyseal ends and resorption of cortical bone with non-

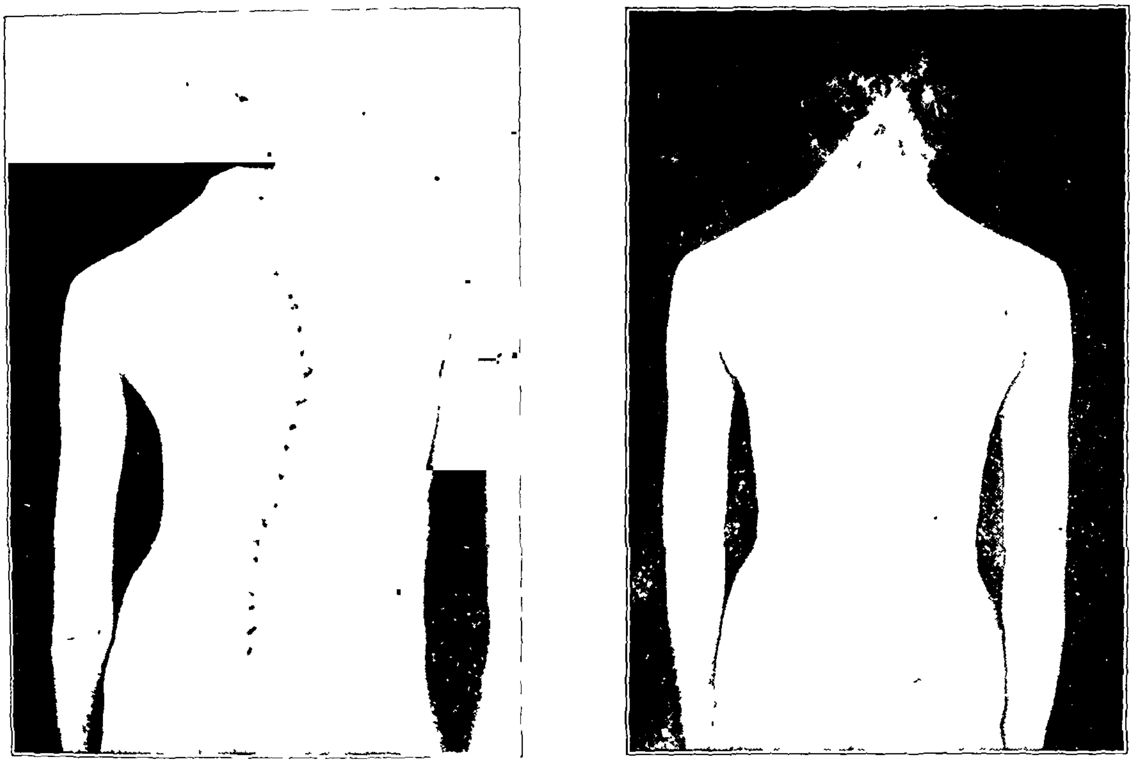

FIG. 9-A FIG. 9-B
Patient with a moderate curve, shown before correction and at end result.

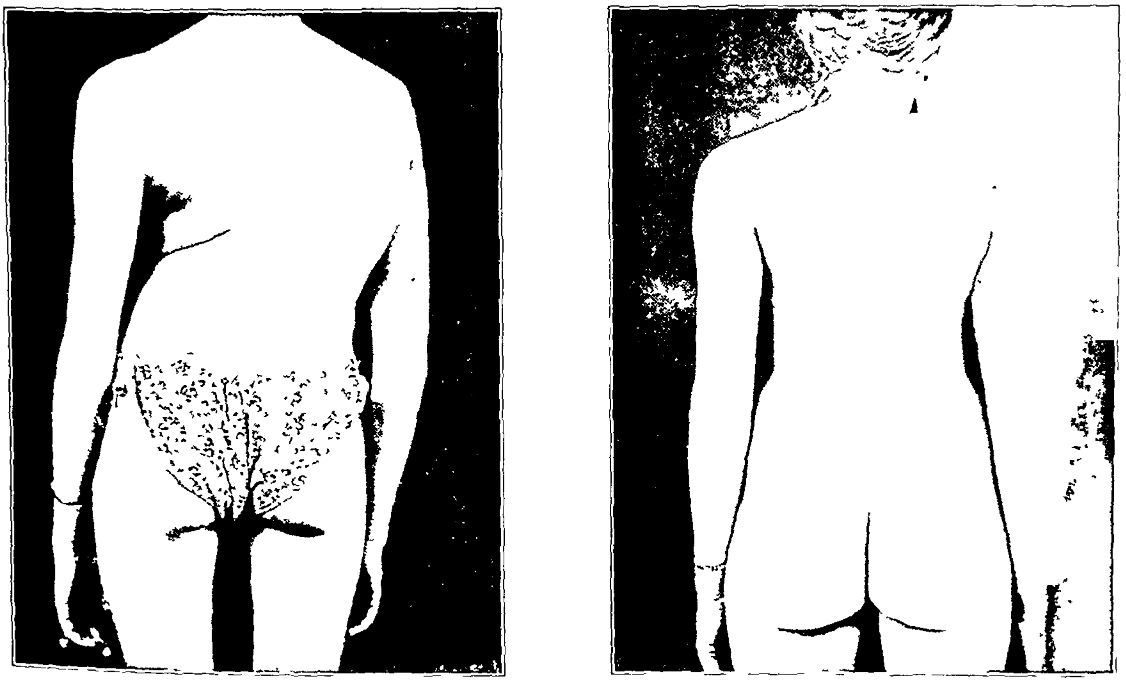

FIG. 10-A FIG. 10-B
Photographs of a severe curve, shown before correction and at end result.

and in the Risser jacket to 32 degrees; a 53-degree curve was corrected to 39 degrees in the hammock and to 20 degrees in the jacket; a 63-degree curve became 48 degrees by suspension, but decreased to 34 degrees in the turnbuckle jacket; and an 82-degree curve was decreased in the hammock to 55 degrees and in the Risser jacket to 47 degrees. All of these patients were suspended in the fish net from one week to one month before being placed in the Risser jacket. However, the mild curve of 17 degrees and the moderate curve

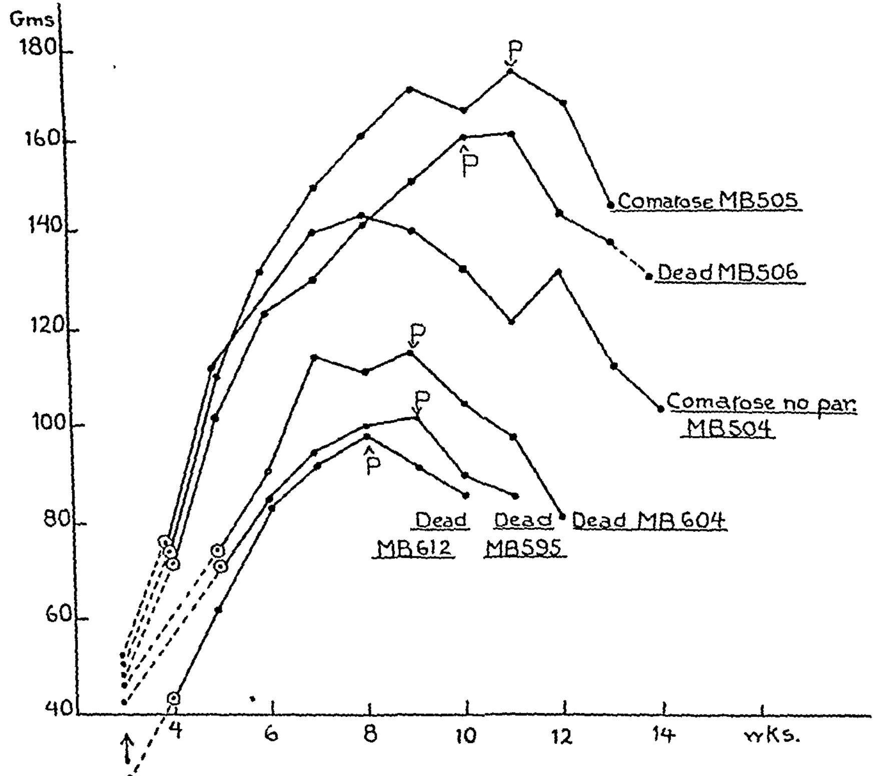

FIG. 8

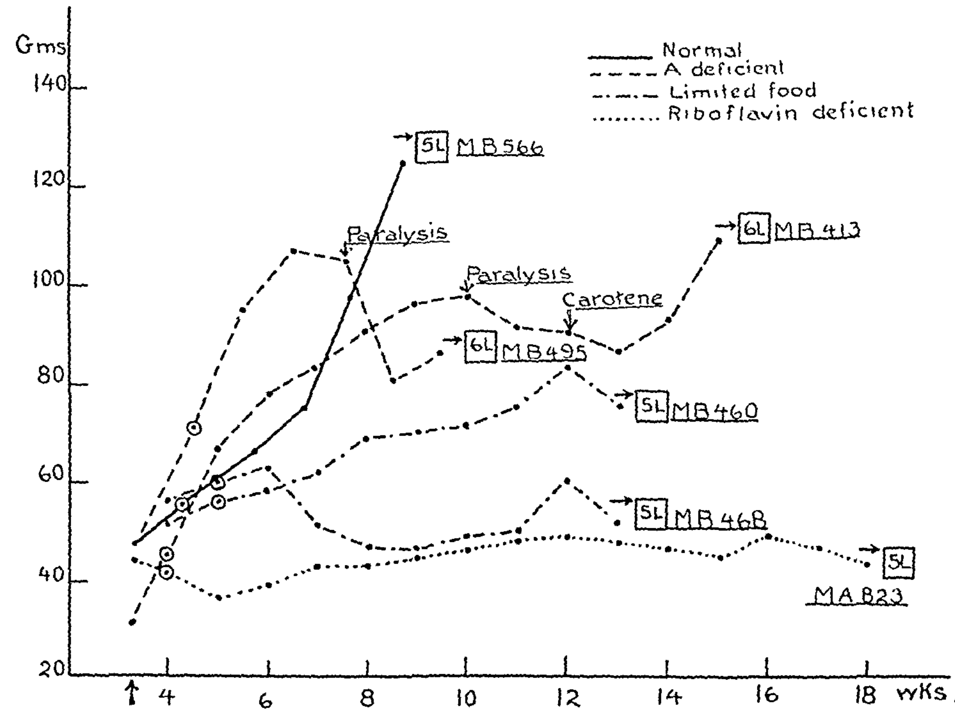

FIG. 9

Fig. 8: Weight curves of weanling rats on vitamin-A-deficient diet. To illustrate onset of paralysis, indicated by *P*, in relation to weight gain.
Fig. 9: Weight curves of two vitamin-A-deficient rats with onset of paralysis indicated. Two weight curves of rats with inanition produced by inadequate nounts of a complete diet, one weight curve of a greatly stunted rat on a riboflavin-deficient diet, and one curve of a normal rat. The rectangles at ends of the rves represent lumbar vertebrae. The arrows indicate levels of the conus terminalis. Notice that the conus of the vitamin-A-deficient rats is situated more than e length of one lumbar vertebra caudad to the normal and inanition controls (See Fig. 10). All six rats were three weeks old when placed on the experimental ets.

VITAMIN-A DEFICIENCY AND EXCESS IN RELATION TO SKELETAL GROWTH * †

BY S. BURT WOLBACH, M.D., BOSTON, MASSACHUSETTS

Bone is a peculiarly favorable tissue for the study of growth, because growth is not simply increase in size; it involves alterations of form. Bone, we know, undergoes continuous remodelling, rapidly during growth, slowly thereafter; and, because of this and similar responses common in pathological conditions, it is to be regarded as an exceedingly labile tissue. Fortunately, remodelling activities of bone leave a trail which can be read, a trail blazed by etched haversian systems, interrupted lamellae, and denser calcium deposits in the so-called cement lines which separate old from newly formed bone. The agents that cause resorption of bone are probably multiple, one of which will be considered in particular in this study. The information obtained from study of bone pathology and from a few connective-tissue behaviors, observable during cyclic physiological processes, leads to the conviction that all our collagenous structures are as labile as bone, subject to constant processes of resorption and new formation. Failure of such adjustments may be regarded as one consequence of age; such failure, indeed, may be the result of irreversible collagenous compounds, slowly accumulated and not amenable to the processes involved in maintenance.

All vitamin deficiencies that culminate in severe malnutrition (and most of them do) arrest growth of bone. Malnutrition caused by inadequate amounts of a perfect diet also arrests bone growth. In every instance where bone growth has ceased because of general inanition, a sturdy bone with normal contours is the result.

There are three vitamin deficiencies that affect bone growth directly. These are A, C, and D. The operations of A and D in bone growth specifically involve epiphyseal-cartilage-cell activities. In vitamin-C deficiency in growing animals, bone suffers in common with all collagenous structures.

It seems self-evident that lack of a vitamin causes suppression of the biochemical systems in which the vitamin is operative.

Vitamin A is unique, because it is the only vitamin which, as will be shown, when given in quantities greatly in excess of normal requirements, actually accelerates some normal growth sequences.

I have proof that the degree of acceleration of growth sequences bears quantitative relationships to the amount of vitamin A administered, and can be pushed to dramatic and disastrous consequences upon bones. In considering the effects of excessive introduction of vitamin A, we may speculate either in terms of increased reaction velocities or of increase in numbers of biochemical systems.

Vitamin A in deficiency and excess in relation to skeletal growth is my subject. I shall outline some of the premises which have led me to the conclusion that Vitamin A is specifically involved in mammalian skeletal growth. Both a deficiency and an excess of vitamin A affect profoundly the growth of bone. The deficiency suppresses, the excess accelerates epiphyseal-cartilage-cell sequences. I shall outline the consequences of such changes in epiphyseal-cartilage sequences upon the remodelling of bone which is an essential feature of bone growth. I shall present evidence which indicates that remodelling sequences attending growth of bone are induced by a factor elaborated in the maturation of epiphyseal-cartilage cells.

* Twenty-Second Ludvig Hektoen Lecture of the Frank Billings Foundation delivered before the Institute of Medicine of Chicago, March 22, 1946.

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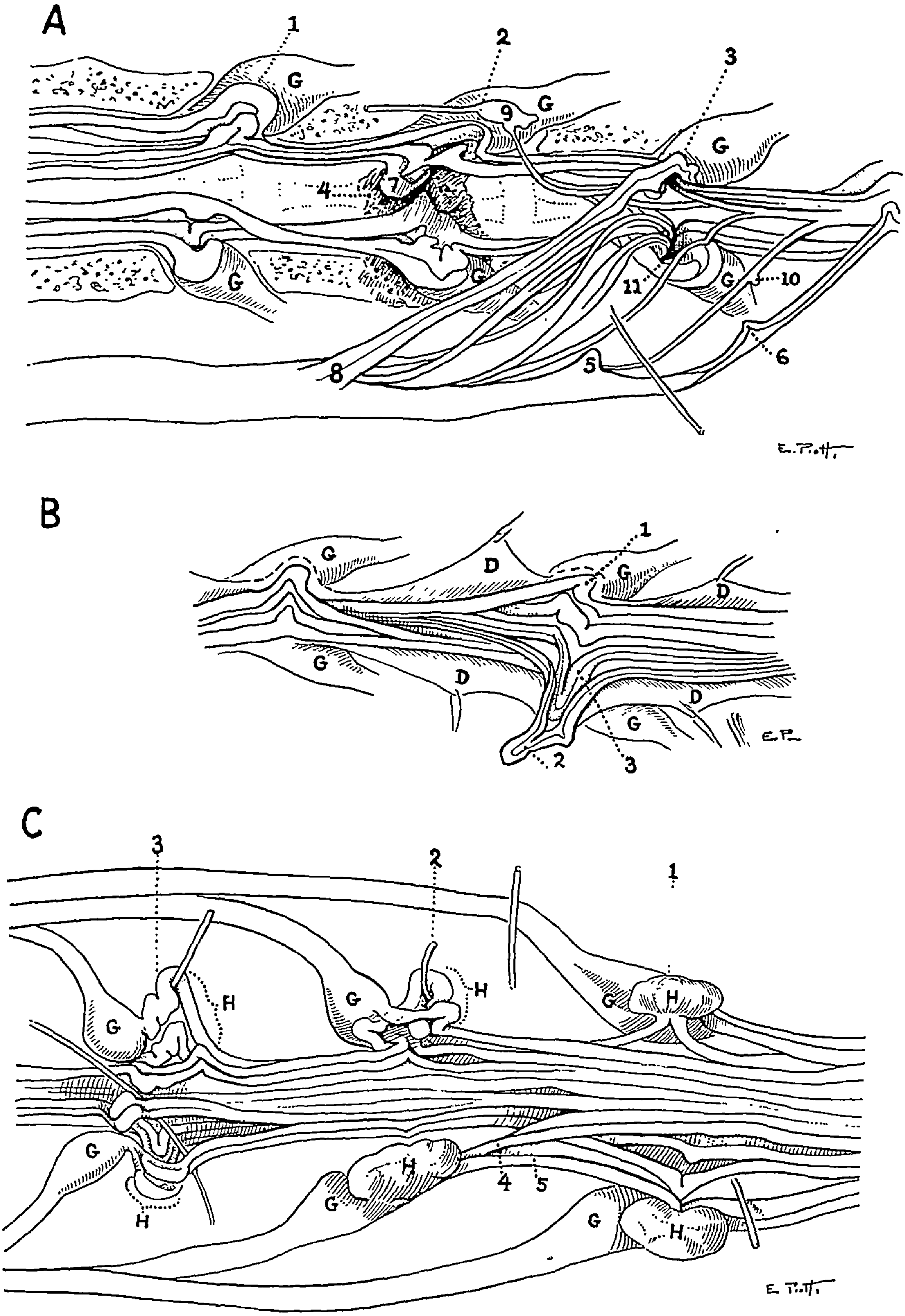

Fig. 11

A. Vitamin-A-deficient rat, ten weeks old, which had shown severe paralysis for nine days; dorsal dissection, exposing third, fourth, and fifth lumbar ganglia, indicated by *1, 2,* and *3*, respectively.

4: Indicates where the body of the fourth lumbar vertebra has been dissected away, exposing coiled nerve roots which have pitted the bone.

5: Herniation of the spinal cord, which was extruded into the right fourth lumbar ganglion.

6: Herniation of nerve roots removed from the fifth lumbar ganglion.

7: Ventral root of the fourth lumbar ganglion, lying in a pit in the body of the fourth lumbar vertebra.

of endosteum and periosteum we refer to as appositional bone formation. Some bone contours, especially those where ligaments, fasciae, tendons, muscles, and dura are attached, are built up by appositional bone formation. The growth of the few bones which developed directly in connective tissue—membraneous bone formation—including the bones of the calvarium, sides of the skull, and most of the facial bones, is by appositional bone growth at the sutures and from periosteum and endosteum. Such bones also undergo remodelling during growth, but I have good reasons for the conviction that the pattern is set by the growth of those bones of the skull which are of cartilaginous origin. In general, endochondral bone formation sets the pace and the pattern of skeletal growth. In the microscopic study of bone, one can usually get a clear picture of what is happening and, indeed, of what has happened, because the remodelling process leaves distinctive features. Regions of resorption are usually indicated by the presence of osteoclasts and breaks in continuity of lamellae. Regions of appositional bone formation can be identified easily by the presence of rows of osteoblasts and non-calcified matrix or osteoid. Where remodelling has occurred, boundaries between resorbed bone and bone subsequently deposited are indicated by cement lines, as well as by discontinuities of lamellae (Fig. 3).

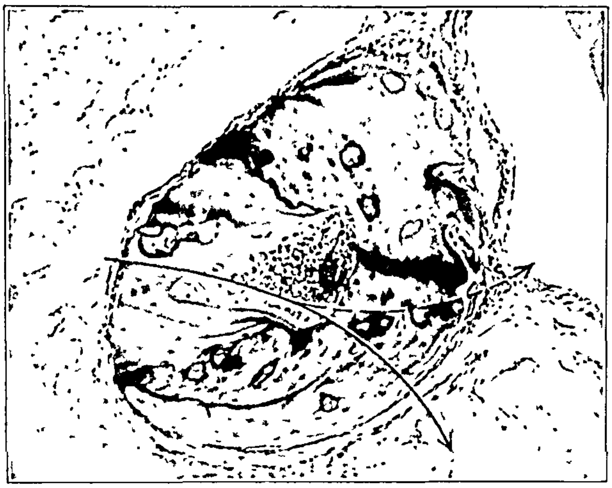

FIG. 3

Cross section of fibula of normal rat to illustrate the pattern of remodelling in consequence of changes in its relation to the tibia, as indicated in Fig. 2. The arrows indicate the outward and posterior swing of this bone.

VITAMIN-C DEFICIENCY

We know of no untoward effect resulting from administration of excessive amounts of vitamin C. Man, monkeys, and the guinea pig are the only animals now known which are unable to synthesize vitamin C. The lesions resulting from vitamin-C deficiency in the young of these animals are the consequence of the failure of formation of intercellular materials. Bone formation, endochondral and appositional, is prevented because of the failure of matrix formation, specifically a failure in the synthesis of the protein or group of closely related proteins,—collagen. All evidence indicates that the physiology of calcification is not involved[15,16].

This failure of bone-matrix formation explains perfectly the gross pathology of vitamin-C deficiency or scurvy in infants. Cartilage sequences in endochondral bone formation continue, but cells accompanying the ingrowing blood vessel can deposit no matrix and hence discontinuity of epiphysis and diaphysis—infraction—takes place. Periosteal cells concerned in appositional bone growth through failure of matrix deposition permit the fibrous periosteum to pull away from bone. Not only is there failure to form collagenous matrices, but there is good reason for believing that resorption of matrices of bone and connective tissue takes place. Remodelling of non-calcified supporting tissues leaves no trail.

The administration of vitamin C to totally deficient guinea pigs is followed by prompt deposition of collagen and formation of the matrices of connective tissue, bone, and teeth. Careful studies by Boyle, Bessey, and Howe have shown that the amount of dentine matrix (predentine) formed is quantitatively related to the amount of vitamin C administered. The relation of vitamin C to growth and maintenance of bone resides solely in its effect upon the formation and maintenance of the organic matrix.

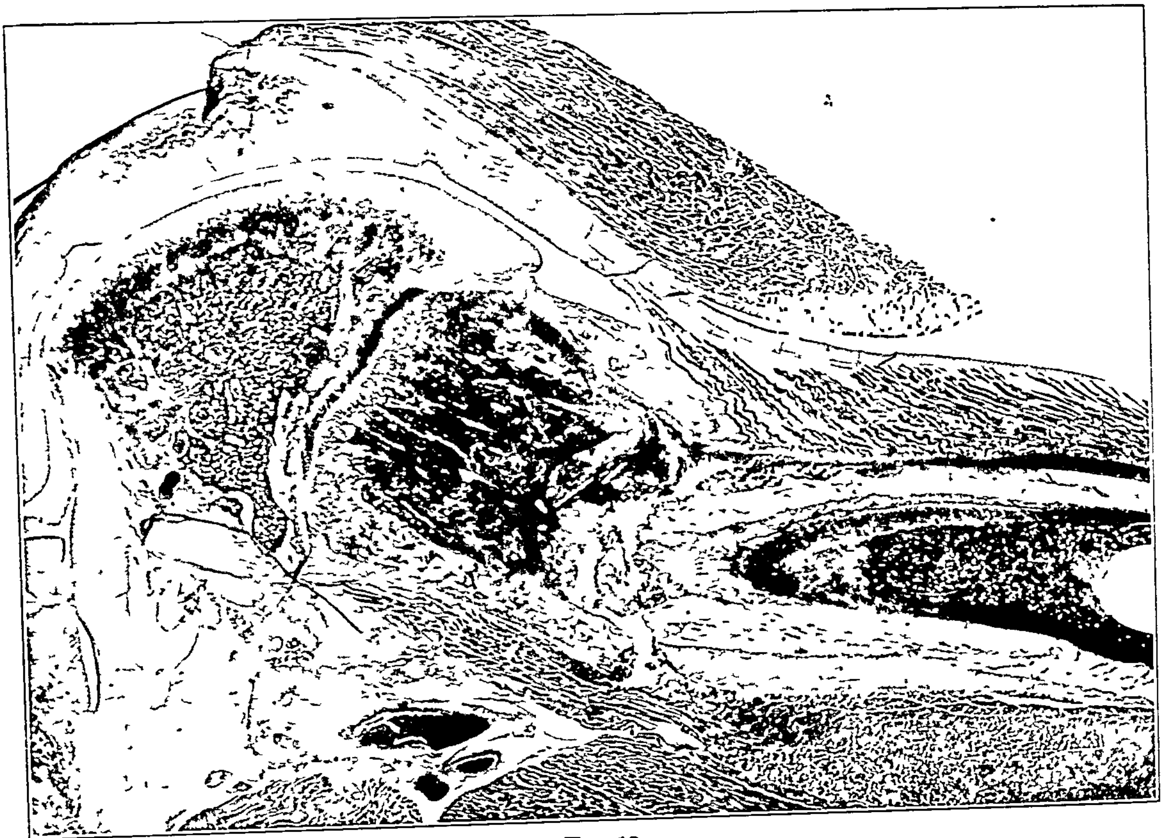

Fig. 12

Fractured femur near distal epiphysis of a rat which received 1250 international units per gram of weight of pure vitamin A for seven days following weaning at twenty-one days of age.

Fig 13

Fracture of upper end of femur of a guinea pig which received 600 international units per gram of weight for twenty-four days. Initial and final weights, 100 and 109 grams. Ascorbic acid was given (60 milligrams, daily) for the last eleven days of the experiment. Note closure of the epiphyses and site of fracture in a region of active remodelling in normal growth.

diaphysis adjacent to the cartilage. The accumulated osteoid and cartilage may become molded or distorted by the pressure of weight-bearing, in cartilage frequently resulting in stratification. In long-continued rickets there is disappearance of trabeculae of the diaphysis and resorption of cortical bone (osteoporosis), in response to more vital needs of the body for calcium.

The first cytological evidence of repair in the rat following vitamin-D therapy is the resumption of cytomorphosis (Fig. 4) visible in twenty-four hours through the presence of cleared or degenerated cells on the diaphyseal border of the cartilage, and accompanied by extensive penetration of capillaries within forty-eight hours, and concurrent calcification of adjacent matrix. The complicated patterns of capillary tufts in the epiphyses of rickets, which have occasioned much discussion and speculation by various authors [11], are satisfactorily explained by the occurrence of irregularly distributed groups of cartilage cells which have completed their sequences, a result of varying degrees of intermittency of the deficiency across the face of the epiphyseal plate. Thus, opportunities for ingrowth of capillaries in lateral and even diaphyseal directions can exist. Such capillary patterns may be seen in the early repair stages of advanced experimental rickets.

Calcification of cartilage matrix and of osteoid first takes place adjacent to capillaries which have entered the spaces left by the degenerated cartilage cells, wherever this has occurred. Subsequently the calcification of accumulated osteoid progresses toward the diaphysis. Excess osteoid, which has accumulated as a result of the deficiency, is removed only after calcification by osteoclasis. Apparently there is no mechanism for the removal of non-calcified bone and cartilage matrices.

Thus in rickets, two separate processes are involved,—one the failure of epiphyseal

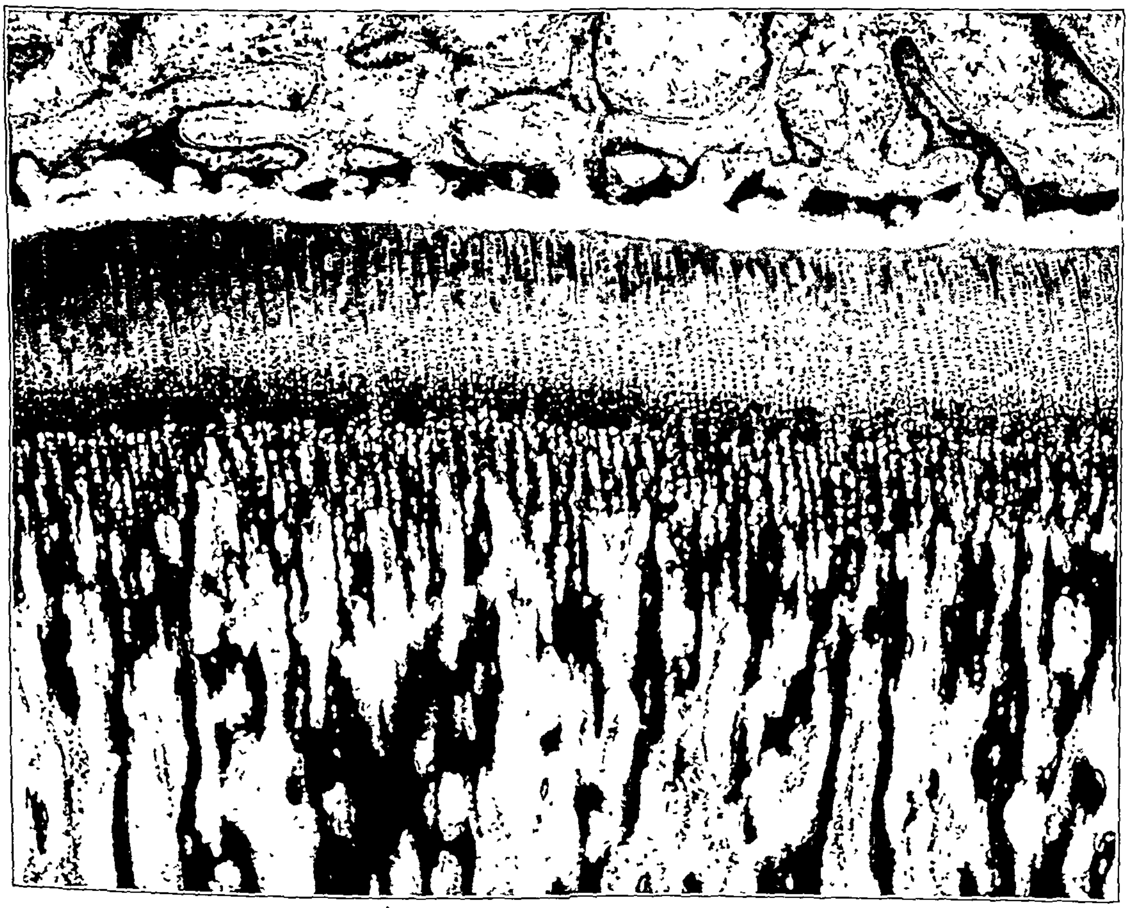

Fig. 5

Proximal epiphysis of tibia of normal litter mate, control puppy to the vitamin-A deficient puppy, the source of Fig. 6.

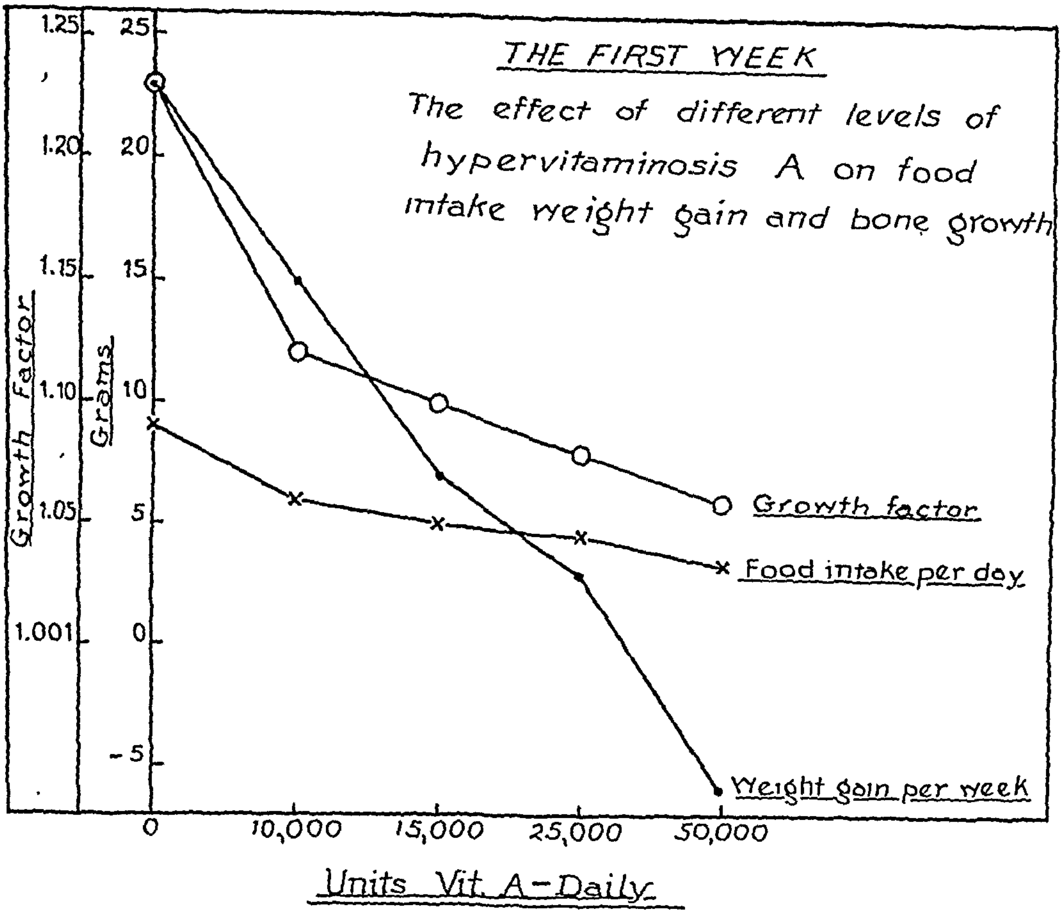

FIG. 15

Curves to show the relation of dosage of vitamin A to growth of a long bone (tibia), food consumption, and weight. All observations were upon weanling rats, twenty-one days of age; approximate weight at this age is forty grams. All measurements of bone were made from x-ray films, made daily. The values of growth given represent the percentage linear growth during one week. These curves are of little value except for documentation of the statement in the text, that rate of remodelling induced by vitamin A is independent of linear growth of bone.

vitamin-A administration are the same when correlated with the normal growth patterns of the bones, and can be precisely expressed in terms of accelerated sequences normal to the species and, in general, are the same as those of rats and guinea pigs.

In rats and guinea pigs there is great acceleration of all processes of bone growth which can be followed microscopically,—specifically, epiphyseal-cartilage sequences and the resorption of bone and appositional bone formation necessary in the remodelling of bone in skeletal growth.

In both species, fractures of long bones are produced in six to ten days, somewhat earlier and more frequently in rats than in guinea pigs (Figs. 12 and 13). The explanation of this difference may reside in the fact that in guinea pigs the epiphyses close, whereas in the rat many epiphyseal cartilages persist throughout life. In both species there is greatly accelerated maturation and degeneration of the epiphyseal-cartilage cells with concurrently rapid replacement by bone. In guinea pigs given excessive amounts of vitamin A (1000 to 1250 international units per gram of weight) from the age of ten days, the distal epiphysis of the femur and the proximal epiphysis of the tibia can be made to close in from ten to fifteen days—or at twenty to twenty-five days of age (Fig. 14). These epiphyses normally close after thirty and sixty weeks of age respectively [20]. In the rat, the adult marrow zone of quiescent epiphyseal cartilage may be attained in the same time period.

It was not difficult to prove, by means of serial sections of long bones (femur and tibia and fibula), that the accelerated remodelling processes were responsible for the production

calcified matrix deposition of periosteal and endosteal origin. These changes have led one group of authors [5,6] to regard the effect as rachitic in type, in spite of the fact that epiphyseal-cartilage-cell sequences are not suppressed. The persistence of essentially normal cartilage-cell sequences under conditions which cause resorption of bone and prevent calcification of newly deposited bone matrix suggests either that the cartilage cells participate in alterations of equilibrium conditions affecting calcium, or that they do not require calcium but do require vitamin D for the sequence of growth, maturation, and degeneration. A single massive dose of activated ergosterol [1] causes a great rise of serum calcium, followed by deposition of calcium salts in many soft tissues concurrently with the fall in serum calcium.

VITAMIN-A DEFICIENCY

In vitamin-A deficiency, all epiphyseal-cartilage sequences cease (Figs. 5, 6 and 7). Cells cease to divide, and cells which have reached almost mature size undergo no further change. Only those cells which have progressed to the vesicular stage continue to change and finally disappear, permitting vascular penetration. The cartilage trabeculae calcified before the deficiency was established are resorbed by osteoclastic action. The matrix of the now atrophic epiphyseal cartilage becomes densely calcified for a depth of a few cells on the diaphyseal border, and eventually a thin bony plate is formed across the face of the epiphyseal disc. The resulting appearance is similar to that produced by inanition from inadequate amounts of a perfect diet, or by inanition resulting from other vitamin deficiencies not specifically related to bone growth,—such as riboflavin and pyridoxine. However, in inanition from these various causes, the growth of all tissues is correspondingly retarded; whereas, in vitamin-A deficiency, endochondral bone growth ceases before the growth rate of the animal as a whole is seriously affected (Figs. 8 and 9). It is this disproportionate growth of the skeleton and soft tissues which is responsible for early disastrous consequences in the young of rats, dogs, guinea pigs, and chicks, because the cranial cavity and the spinal canal become too small for the central nervous

FIG. 7

Distal epiphysis of femur of rat, to illustrate the return of normal cartilage sequences and bone growth, follo[illegible] severe vitamin-A deficiency. Note the plat[illegible] diaphyseal side.

the mechanism of endochondral or replacement bone growth. Vitamin-A deficiency suppresses epiphyseal-cartilage-cell sequences and hence endochondral bone growth. Remodelling sequences, involving concurrent resorption of bone with bone deposition and replacement of cancellous bone by compact bone, cease to operate. Appositional growth of bone of periosteal origin continues, until inanition supervenes, *at a rate in conformity to the normal growth pattern in each site. Skeletal growth as a whole ceases.*

Excessive vitamin-A administration accelerates in general those growth sequences of bone retarded by the deficiency. It causes rapid consumption of epiphyseal cartilage and, in appropriate species, greatly premature closure of epiphyses; also, excessive rapidity of remodelling processes unrelated to linear growth of bones, but *definitely related to rate of epiphyseal-cartilage-cell cytomorphosis.* Both the rates of remodelling processes and of cartilage-cell sequences are quantitatively related to the amounts of vitamin A administered. Substitution of compact bone for cancellous bone in conformity to normal growth patterns is greatly accelerated. The fractures and sites of occurrence are fully explained by acceleration of remodelling. Bone which does not require remodelling for maintenance of the normal growth pattern is not responsive to the excess vitamin introduced.

Application of the facts presented will explain easily and completely the results of vitamin-A deficiency upon any of the simpler bony structures of the skeleton. In the case of the skull, the problem is a complicated one, because of the intimate relations of the individual bones to one another in the absence of joints, and because of the many epiphyses or sites of endochondral bone growth and directions of such growth in the bones comprising the base of the skull. However, here too the changes in bones at the base of the skull, in-

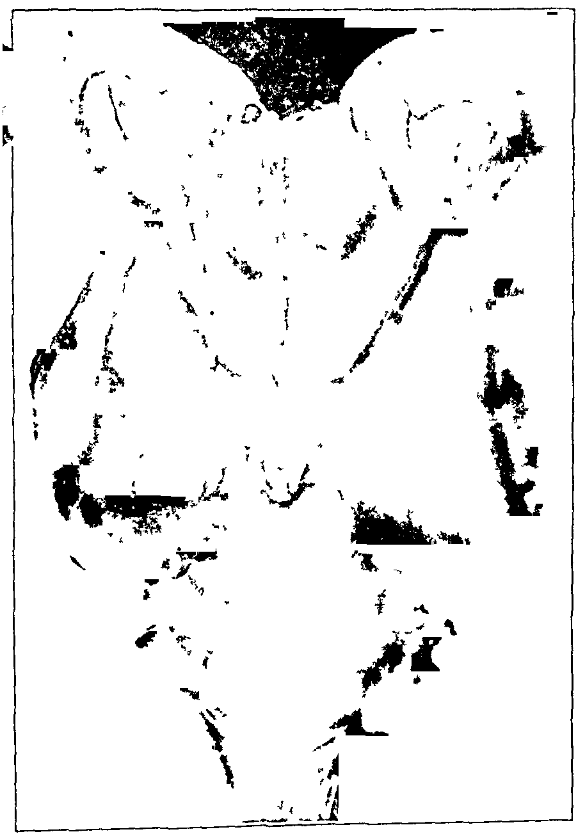

FIG. 20

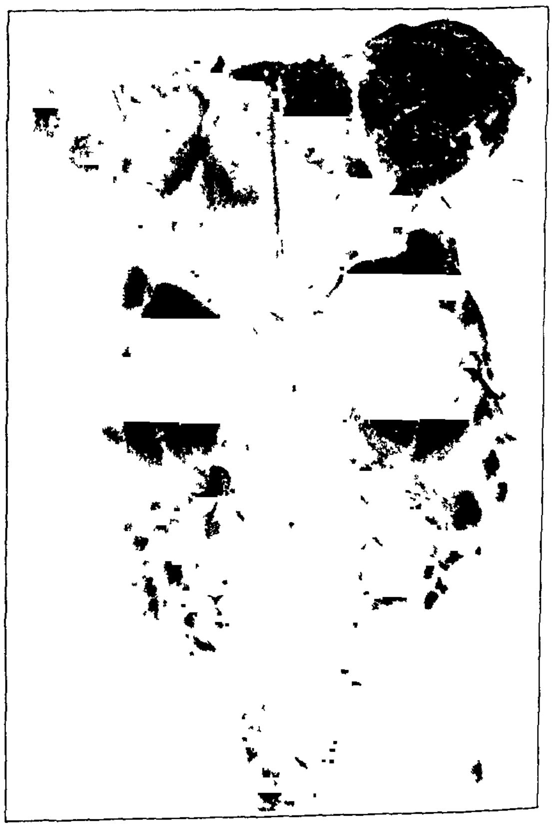

FIG. 21

Fig. 20: Dissection of the optic tract of a normal litter mate, control puppy for comparison with Fig. 21, made from a vitamin-A-deficient puppy. Both of these dogs were thoroughly injected with formaldehyde immediately after sacrifice, so that the central nervous system was thoroughly hardened *in situ.*

Fig. 21: Vitamin-A-deficient litter mate of puppy of Fig. 20. Notice the tortuosity of the optic nerves in the orbit; also, compression deformities of cerebrum and cerebellum. The tortuous optic tract is evidence of failure of dimensional increase of the bony orbit in a region which excludes deformation by pressure of bone.

system which continues to grow at approximately normal rate until general inanition supervenes. The result of the disproportionate growth of bone and central nervous system is overcrowding of spinal canal and cranial cavity and paralysis, resulting from mechanical pressure upon brain, spinal cord, and nerve roots. The consequences are exhibited by multiple herniations of the cerebrum and cerebellum into arachnoidal villi, dislocation of the brain as a whole toward the foramen magnum, and buckling and herniation of nerve roots (rat and guinea pig) into intervertebral foramina and into the bodies of vertebrae. The latter is the result of atrophy of bone, caused by the pressure of buckled nerve-root trunks (Figs. 10 and 11).

Species differences in anatomy and growth patterns naturally affect the details resulting from the disproportionate growth. While identical in rat and guinea pig, there are as yet incompletely solved differences in the dog to which reference will be made later. In the chick, there are no herniations of nerve roots, because the spinal cord, unlike in most mammals, fills the entire spinal canal, and the roots leave the spinal cord through foramina at the levels of their origins in the spinal cord. However, overcrowding of the central nervous system is strikingly shown by distortion of the brain with voluminous herniations into arachnoidal villi and marked distortion of the spinal cord, shown by the cross ribbing in the lumbosacral region, which is produced by the bulging of the spinal cord into the ribbed spinal canal of this region.

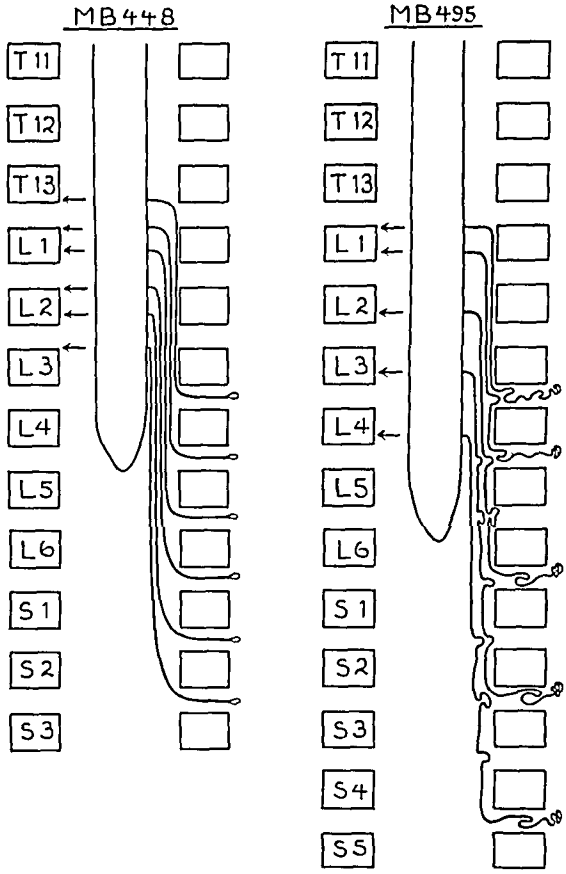

FIG. 10

Diagrams. *MB 448* illustrates the position of the conus terminalis in normal rats. The arrows indicate levels of origin from the spinal cord of a few nerve roots in relation to their foramina of exit.

MB 495 illustrates the position of the conus terminalis in a vitamin-A-deficient rat. (See Fig. 9 for weight curve.) Also, a few nerve roots are shown for sites of herniations and for levels of origins in relation to foramina of exit. This diagram is a partial record of the dissection of rat MB 495. Notice several nerve roots with multiple herniations and the low position of the conus terminalis which has resulted from the continued growth of the central nervous system after growth of the skeleton was retarded.

Cessation of endochondral growth is not the whole story of the effect of vitamin-A deficiency upon young bones; remodelling ceases and appositional bone formation continues at different rates in locations which vary with the species, but which are in conformity with each normal growth pattern.

The long bones of vitamin-A-deficient animals are shorter and thicker than those of normal animals. The shortness of the long bones is the result of failure of endochondral bone growth. The increased thickness is produced by continued appositional bone growth and, near the ends of bones, by retardation of remodelling sequences in the final period of growth before complete deficiency is established. Mellanby has paid particular attention to apparently excessive periosteal bone formation in relation to the bony labyrinth of the ear, other bones of the skull, and cervical vertebrae. Wolbach and Bessey in their 1941 paper confirmed Mellanby's findings in regard to the changes in the petrous bones of dogs, and recorded similar findings in A-deficient rats and guinea pigs. In none of Mellanby's publications [7,8,9] is mention made of epiphyseal cartilages and endochondral (replacement) bone growth.

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FIG. 11 (*continued*)

8: Dorsal roots to the sixth lumbar and first sacral ganglia from their origin to herniation into the fifth lumbar ganglion.
9: Herniation of a coiled and swollen unidentified nerve root, removed from the invaginated fourth lumbar ganglion.
10: Small excrescence on the ventral nerve root removed from a fifth lumbar ganglion.
11: A deep pit in the fifth lumbar vertebra with entering and emerging nerve roots.
G: Ganglia.

B. Vitamin-A-deficient rat, eleven weeks old, which had shown severe paralysis for twenty-one days; dorsal dissection, exposing fifth and sixth lumbar ganglia with herniated nerve roots.
1: Ventral root of the first sacral ganglion, herniated into the sixth lumbar, left side.
2: Dorsal and ventral roots of the third sacral ganglion, right, removed from herniation into the sixth lumbar ganglion, right.
3: Dorsal and ventral roots to the second right sacral ganglion, dislodged from herniation into the right sixth lumbar ganglion.
G: Ganglia.
D: Dura. Its line of attachment to the ganglion is represented by dotted lines.

C. Vitamin-A-deficient rat, ten weeks old, which had shown severe paralysis for nine days; ventral dissection. The bone was dissected away from the herniation occupying pits in the bodies of the fourth, fifth, and sixth lumbar vertebrae, indicated respectively by *1*, *2*, and *3*. *H* indicates herniation; *G*, ganglia. The herniations in relation to the fourth lumbar ganglia are covered by membranes. Partial dissections have been made elsewhere to give an idea of the complexity of the coils and the irregular thickening of the herniated nerve trunks. *4* and *5* indicate dorsal and ventral roots of the left fifth lumbar ganglion entering the hernial sac.

(Reproduced by permission from *Archives of Pathology*, **32**: 708, 1941.)

My own studies had convinced me, several years ago, that, after endochondral bone formation had ceased in vitamin-A-deficient animals, appositional bone formation continued, and in certain locations apparently became excessive. Restudy of bones from vitamin-A-deficient animals, in the light of information obtained from the study of growth patterns of normal bones and of bones of animals which had been given greatly excessive amounts of vitamin A, has made clear the fact that appositional bone formation in the A-deficient animals continues, until inanition supervenes, *in strict conformity to normal growth patterns, both as to situation and rate.*

Some contours of long bones are formed by active appositional (periosteal) bone formation; examples in the rat are the third trochanter of the femur, the crest of the tibia, and the interosseous crests of tibia and fibula. In such regions the rate of appositional bone formation is much greater than elsewhere. Serial sections of the petrous bones of normal rats and dogs have shown that activity of appositional bone formation varies greatly in different regions,—for example, it is much greater on the internal (medial) side of the recess for the paraflocculus than on the external (lateral) side. In the latter situation in the rat, resorption of bone is active. Other locations of relatively greater activity in relation to the internal auditory meatus and cochlea have been identified, sufficient to warrant the statement that the apparently excessive appositional bone formation in the vitamin-A-deficient animal also is correlatable with the pattern and rate of formation of the normal of the two species. The normal pattern of this region in the rat is somewhat different from that of the dog; likewise the untoward consequences of the deficiency in the two species.

Both in rat and dog, the replacement of cancellous bone by compact bone, which occurs in normal growth and remodelling sequences, ceases. This feature of the deficiency is particularly well exhibited in the bones of the dogs' calvarium and vertebrae.

In the chick (age of experimentation from day of hatching to three or four weeks), I have been unable to find any continuation of appositional bone growth other than a slight degree of generalized appositional bone growth of all bones. The general picture is that of greatly reduced bone growth, resulting in cessation of endochondral bone growth, great diminution of trabecular bone and of cortical bone, and great retardation of compact bone formation.

In no situation have I found evidence of untoward pressure effect upon the nervous system, resulting solely from local, apparently excessive, appositional bone growth.

Before further consideration of the thesis that all *appositional* bone growth in vitamin-A deficiency is the result of the carrying out of a normal growth pattern, an account

FIG. 2-A

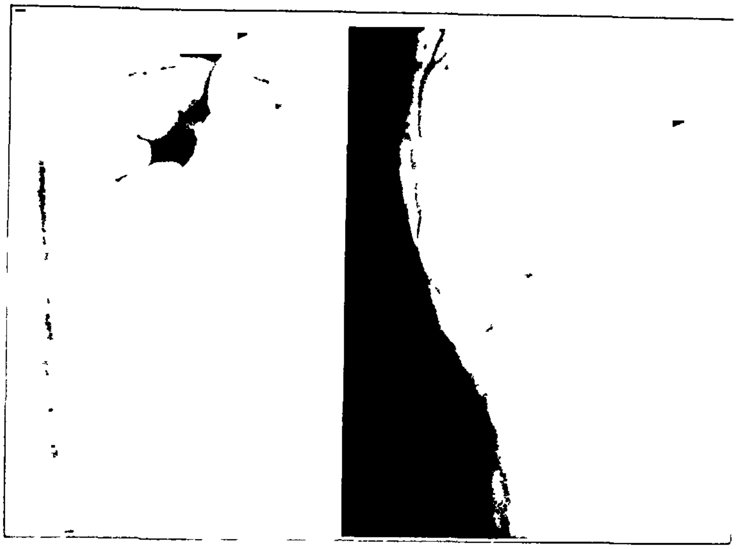

FIG. 2-B

Fig. 2-A: Case N. H. Photograph showing amount of flexion in hand before surgery. The index finger had previously been amputated.
Fig. 2-B: Photographs showing motion in the metacarpophalangeal joint of the middle finger after arthroplasty.

anaesthetic, is deformed, or lacks flexor tendons, an arthroplasty will not improve th function of the hand much, no matter how good a joint is made. If there is excessiv shortening of the metacarpal, arthrodesis may be indicated.

Technique of Arthroplasty

An incision, approximately five centimeters long, is made over the dorsolateral aspect o the joint. The joint is exposed through the space between the interosseus and extensor ten-

FIG. 3-A

Case J. W. Roentgenograms showing ankylosis of metacarpophalangeal joint of the middle finger. Note also fracture of proximal phalanx of the index finger, causing limited motion in that digit.

of the consequences of excessive vitamin-A administration upon growth of young animals—rats, guinea pigs, and dogs—is necessary.

HYPERVITAMINOSIS A

Fractures of the long bones of rats following the administration of excessive amounts of fish-oil concentrates, presumably the result of the vitamin-A content, were reported by Collazo and associates in 1929[19]. A brief review of the subject has been written by Wolbach and Bessey[19], who also reported that fractures of the bones of weanling rats could be produced in from six to eleven days by the excessive daily administration of pure vitamin A. No complete explanation of this disastrous effect upon growing bones was given, but we did write: "An hypothesis we hold at the present time is that the early consequence of excessive vitamin-A administration is the acceleration of some processes of bone growth, notably: (a) periosteal proliferation, (b) epiphyseal-cartilage sequences preliminary to endochondral bone formation, and (c) remodelling of bone attended by osteoclasis".

Continuation of the study of hypervitaminosis-A effects upon bone growth has been made possible through the assistance of Dr. O. A. Bessey of the Public Health Research Institute of New York, Dr. P. R. Howe of the Forsyth Dental Infirmary, Dr. D. M. Hegsted of the Harvard School of Public Health, Mr. Thomas Van Metre, medical student, and Dr. Charlotte Maddock, Research Fellow in Pathology.

The following résumé of observations and conclusions is based upon the study of many rats and guinea pigs. Many chicks, a few mice, and two puppies were also studied. Because the growth pattern of young chicks is quite different from that of the mammals studied, and because too few mice and dogs were used, this account is based upon the experiments with rats and guinea pigs. *However, in all species, the results of excessive*

FIG. 14

From distal end of femur of guinea pig, illustrating early closure of the epiphysis. From nine days of age, this guinea pig received approximately 600 international units of vitamin A per gram, plus 120 milligrams of ascorbic acid for eighteen days, at which time it was killed. The large amounts of ascorbic acid did not influence the effect of the excessive vitamin A administered.

of fractures; nor was it difficult to prove that the accelerated sequences, though disastrous in their consequences, were in complete conformity to normal growth patterns in character and localization. My first assumption was that the rate of remodelling was a function of linear growth. This logical rationalization had to be abandoned in light of the fact that in guinea pigs the remodelling sequences leading to fractures were in progress concurrently with the rapid consumption and ossification of the epiphyseal cartilages. Comparisons of the growth rates of the long bones of normal rats and litter mates receiving excessive amounts of vitamin A, by means of x-ray films were undertaken. The results showed clearly that in the first week, which covers the period in which fractures usually occur when large amounts of vitamin A are given, linear growth rate of bone is retarded, together with a decrease of food consumption and growth of the rat as a whole. The larger the amounts of vitamin A administered, *the greater is the retardation of growth and the greater is the rate and frequency of fracture* (Figs. 15, 16-A, 16-B, 16-C, and 16-D). The microscopic sequences tally perfectly with the gross changes. There is no evidence of increased rate of multiplication of cartilage cells; in fact, in both rats and guinea pigs, mitoses are fewer than in normal controls. Common to both guinea-pig and rat epiphyseal-cartilage sequences is the accelerated rate of growth, maturation, and death (cytomorphosis). The conclusion is warranted that an agent contributed by the dying or death of this specialized tissue—which maintains, until maturity of vertebrates, sequences essential to growth most commonly exhibited in the embryo and foetus—is responsible for the remodelling process of bone growth. Therefore, we may discard the simpler explanation that bone remodelling during growth is a response to shifting mechanics of the skeleton and musculature, and take recourse to the subtler processes revealed by experimental embryology and connoted by the term *induction*. In the present instance, epiphyseal cartilage is the *organizer* or *inductor*; the bone that undergoes resorption with concurrent appositional growth in conformity to a pattern is the *competent* tissue.

FIG. 16-A FIG. 16-B

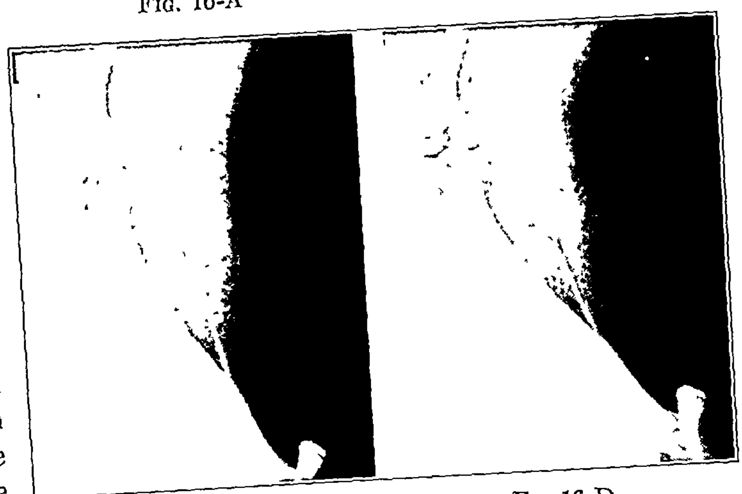

FIG. 16-C FIG. 16-D

Four roentgenograms illustrating the effects of large *versus* relatively small doses of vitamin A upon the tibiae of rats.

Fig. 16-A: Normal 28-day-old rat.

Fig. 16-B: From 28-day-old rat which received 1250 international units per gram of weight for seven days prior to sacrifice.

Fig. 16-C: Tibia of a rat which received 250 international units per gram of weight from twenty-one days to sixty-nine days of age.

Fig. 16-D: Same rat with treatment continued to eighty-fifth day of age. The length of the tibia is within normal limits. The striking features are the thinness of the shaft and the contours near the epiphyses.

No attempt is made here to give a full account of the microscopic details of the effect

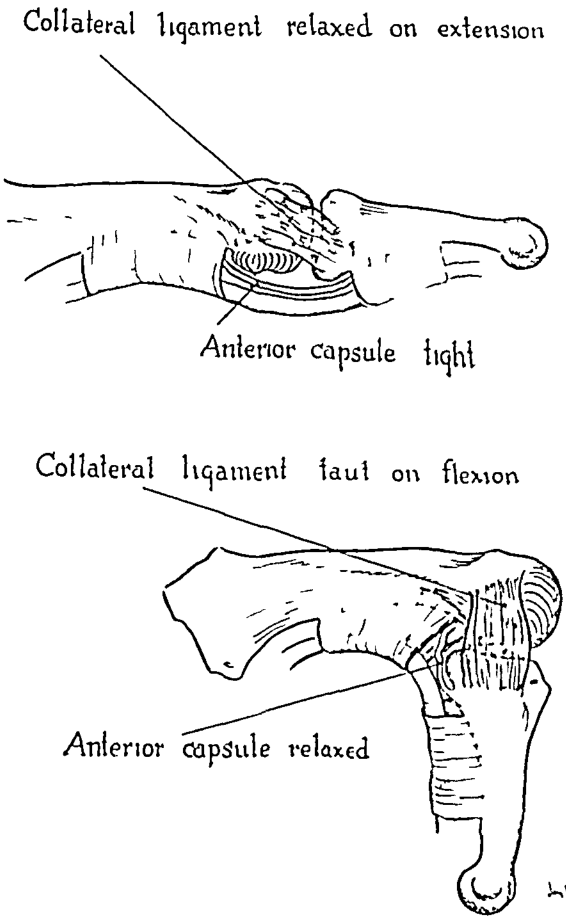

FIG 5-A

Showing collateral ligaments of the anterior capsule in a normal joint

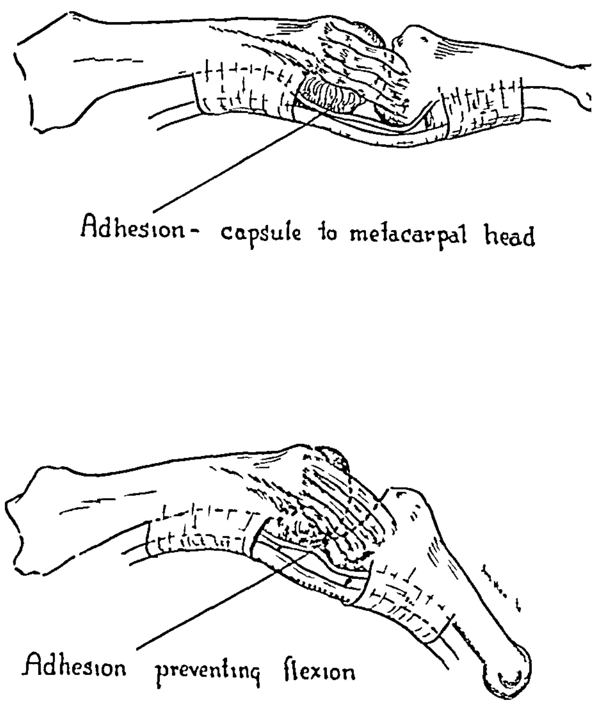

FIG 5-B

Showing the mechanism of limited flexion in a stiff metacarpophalangeal joint where joint surfaces are intact Flexion is prevented because of short collateral ligaments and adhesion of the anterior capsule.

in the presence of swelling and in the absence of proper splinting. The same situati exists in a metacarpal fracture with bowing which tightens the extensors and relaxes t intrinsic muscles by shortening the distance between their origin and insertion. Bei short small muscles with a low amplitude of excursion, the interossei and lumbricales not adapt themselves well to shortening of the distance between their origin and insertio as do the long forearm muscles. Flexion contracture of the wrist tightens the extensi tendons and causes them to overbalance the intrinsic muscles. Extensor tendons whi are tight, due to adhesions or pathological changes in the muscles, are common and are difficult problem. Severe wounds of the forearm are generally splinted, with the wrist a fingers extended, so as to approximate destroyed muscles or tendons. It is necessary ar proper to extend the wrist but, if the fingers are held extended in a patient where tendo graft or transfer is later indicated, they will be held in such a position by adhesions. A least one extra operation is necessitated to obtain flexion, and even then the end result tendon transfer or graft is likely to be compromised. Poor nutrition in the hand, with sulting vessel and nerve lesions, greatly accelerates the pathological changes in the joi and makes them much more resistant to treatment.

Capsulotomy is indicated on metacarpophalangeal joints fixed in extension, if t joint surfaces are intact and if they cannot be mobilized with physical therapy and tr tion. In the patients of this series, traction was not continued beyond three weeks, if th was no inclination of the joint to yield. Capsulotomy is frequently done in connect with other operations,—such as nerve suture, bone graft to metacarpals, tendon transf skin grafts, and arthrodesis of the wrist. It cannot be successfully combined with operation which necessitates extension of the metacarpophalangeal joint following sur or with a flexor-tendon graft. Extreme caution must be exercised if a capsulotomy is d

cluding the petrous bone, are precisely correlatable with normal growth patterns. The remodelling of the calvarium presents an interesting problem, because the increase of cranial capacity is the result of area increase of the enclosing bones. Growth at the base in bones of cartilaginous origin ceases. The bones of the calvarium of membranous origin normally increase their areas by appositional bone growth at the sutures. Change in radii of curvature also takes place as the cranial capacity increases. In the normal, these two features of growth—area increase of individual bones and changes in curvature—result in a pattern of growth of the membranous bones, in which there is resorption of bone on the exterior of the skull and deposition of bone on the interior surface. This remodelling of flat bones of the skull is suppressed in vitamin-A deficiency, as well as the remodelling of bones of cartilaginous origin, and results in thicker bones, cancellous in structure. One illustration of the fact that the growth of the skull as a whole is suppressed is the fact that in rats and dogs the extracranial lengths of the optic nerves are tortuous, because they become longer than the size of the orbits require (Figs. 20 and 21).

We may conclude that the pattern of bone growth is determined by epiphyseal-cartilage activities for which vitamin A is as essential, apparently without the intermediation of other organs, as it is in vision. We may deduce that in the maturation of the cartilage cells there is produced an inductor factor which is responsible for the maintenance of remodelling of bone during the growth period. Because the accelerated remodelling processes caused by excess of vitamin A adhere precisely to the normal growth pattern, bone which disappears during growth may be referred to as competent bone.

Recent crude experiments in which finely comminuted epiphyseal cartilage from calves has been injected into young rats have yielded results which indicate the correctness of the deduction that epiphyseal cartilage is the source of a factor or factors governing the remodelling of bone during growth.

The effects we have obtained do not duplicate in several ways those produced by excessive vitamin-A administration; nevertheless, they are quite distinctive and unlike those of any other agent affecting bone growth. Briefly, they are the continuation of normal epiphyseal-cartilage sequences, premature resorption of the trabeculae of the primary spongiosa, and, therefore, failure of incorporation of trabecular bone into cortical bone near the epiphyses, and great resorption of cortical bone at sites of remodelling. Osteoclasts are much less numerous than in excessive vitamin-A experiments, and appositional bone formation is not accelerated. Such bones have fractured in the course of handling the rats.

While the cartilage-injection experiments have yielded results of the general nature of acceleration of remodelling, important features of the normal processes are lacking, conceivably because labile factors have been lost in the preparation and preservation of the cartilage prior to injection.

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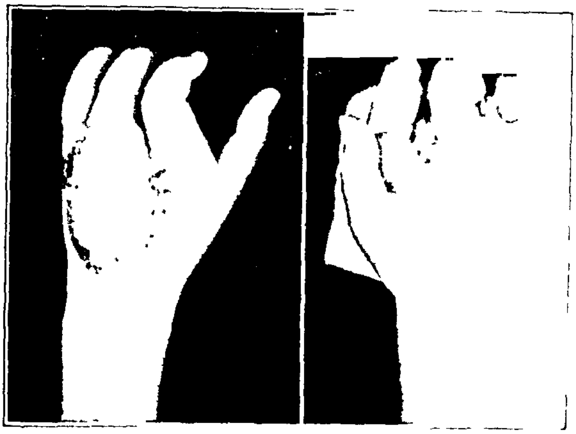

FIG. 8-A

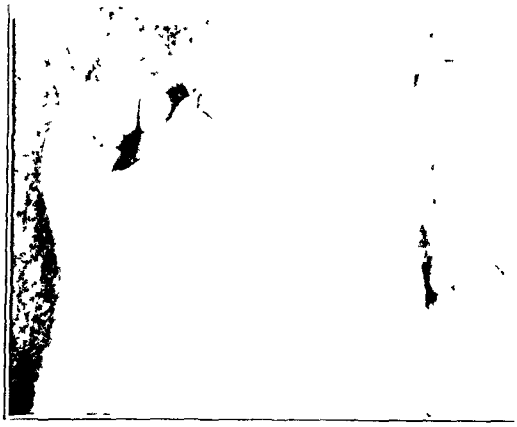

FIG. 8-B

Fig. 8-A: Case C. B. Received severe injury to hand, with traumatic amputation of the mid finger. A pedicle flap had been applied, but had healed poorly. Fingers were stiff, with the me carpophalangeal joint in hyperextension.

Fig. 8-B: Following capsulotomy of all metacarpophalangeal joints. Function is considered exc lent in view of the extreme scarring of the hand.

capsule is often stripped from the metacarpal head, when the joint is forcibly flexed; if it may be reflected from the metacarpal head with a blunt dissecting probe. Occasion following capsulotomy, the extensor tendon will become subluxated to the side of the j when it is flexed. If this condition is allowed to persist, the metacarpophalangeal j cannot be actively extended. It may be corrected by sectioning part of the lateral ex sion of the extensor tendon on the side of the subluxation or by tightening the opp side. If the latter manoeuvre is used, flexion should not be started for one week and sh be obtained gradually by traction. Following surgery, the metacarpophalangeal joints held in flexion, either by rigid splinting or by traction. If it is necessary to release

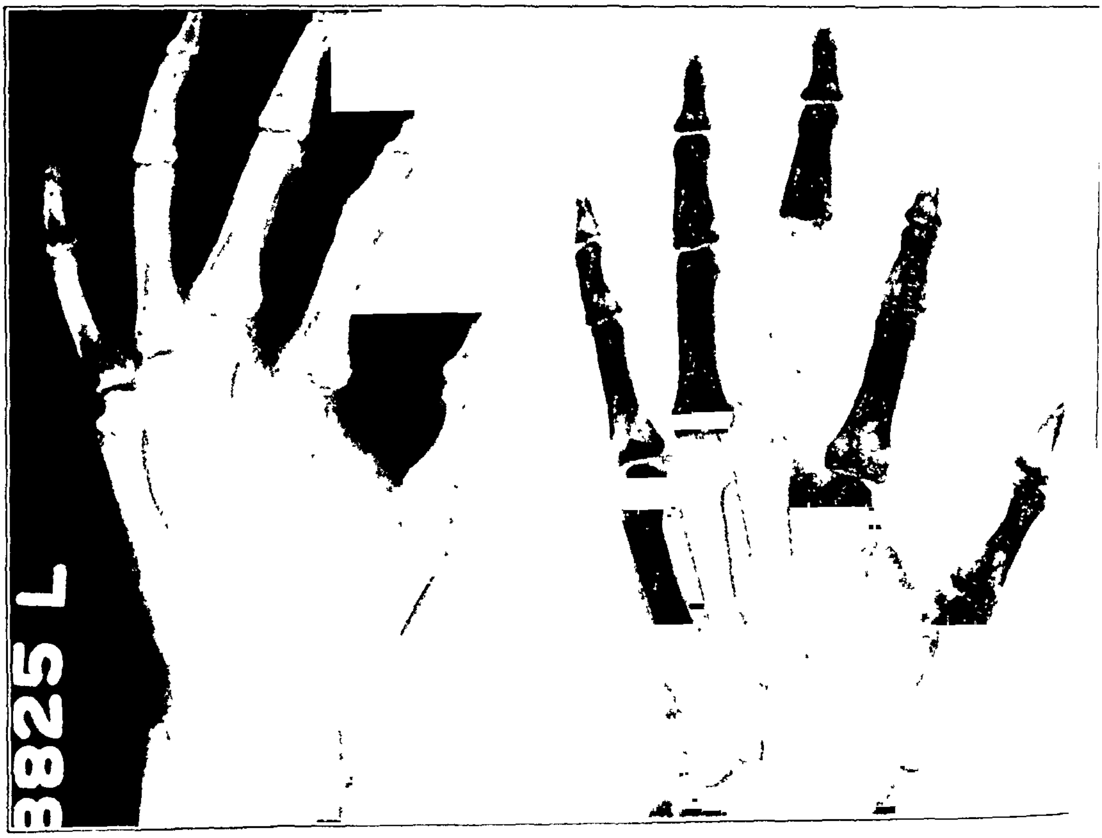

FIG. 9-A

Case R. M. Roentgenograms of hand before surgery.

MOBILIZATION OF METACARPOPHALANGEAL JOINTS

Arthroplasty and Capsulotomy *

BY MAJOR SAMUEL BENJAMIN FOWLER

Medical Corps, Army of the United States

Experiences in World War II have shown that stiff metacarpophalangeal joints are ry common among patients admitted for reconstructive surgery of the hand. They follow ost severe wounds of the hand and frequently injuries higher in the arm, particularly ose wounds which are complicated by osteomyelitis, nerve injury, or large soft-tissue fects. Splinting has been responsible for the stiff joints in a number of cases.

ARTHROPLASTY

In the series of cases upon which this report is based, all the patients requiring throplasty presented destruction of one or both joint surfaces. This destruction was condary to compound comminuted fractures directly involving the joint, except for one se where ankylosis was secondary to septic arthritis following a human bite. The inter-

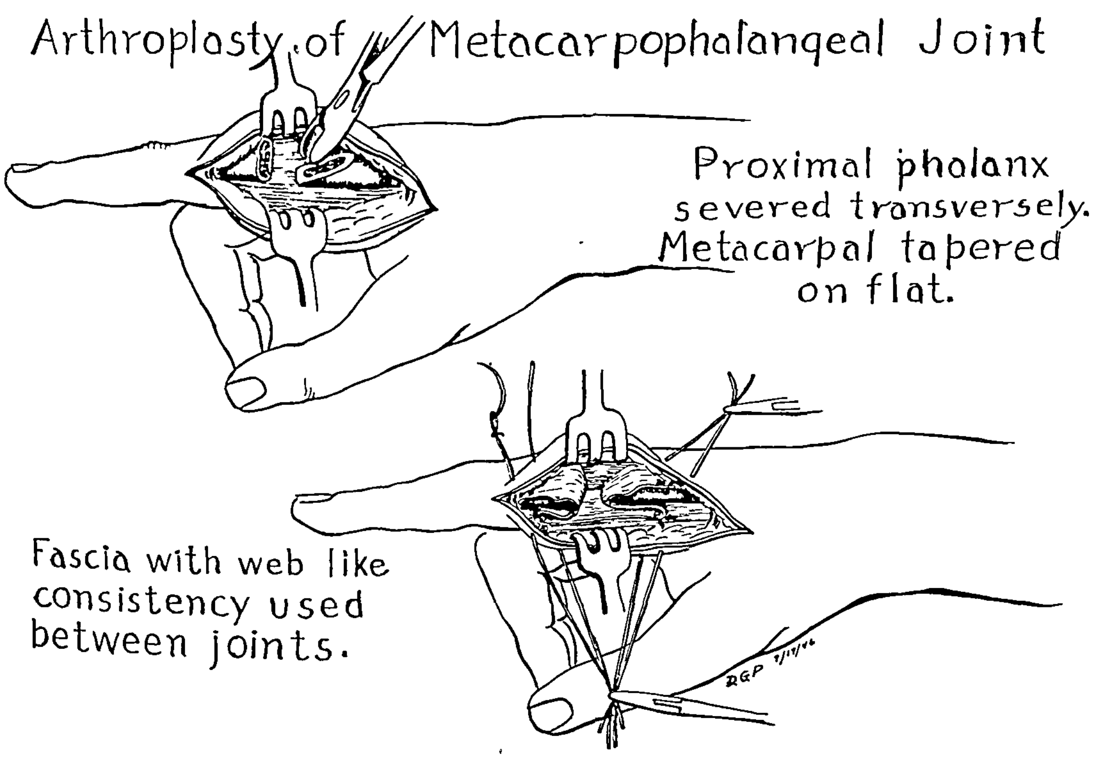

FIG. 1

phalangeal joints were generally stiff to some degree, and the intrinsic muscles were functionless in several cases because of destruction or adhesions. Some infection had probably been present in every case.

Arthroplasty is indicated for ankylosed metacarpophalangeal joints with less than 30 degrees of motion in a useful arc, if mobilization of the joint will restore a practical degree of function to the digit. Arthroplasty of the thumb has not been considered wise in any case of this series and has been done only once in the little finger. If a digit is permanently

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

of the end results involves too many factors for a brief presentation. Factors contr-
to imperfect results are:

1. Failure to excise adequately the collateral ligament, particularly the ext anterior portion;
2. Failure to strip the anterior capsule from the metacarpal head;
3. Failure to keep the joint flexed long enough;
4. Subluxation of the extensor tendon;
5. Muscle imbalance in the hand;
6. Ununited and malunited metacarpal fractures;
7. Poor condition of the local tissues, including cicatrix and deficient circulation

CONCLUSIONS

Arthroplasty and capsulotomy are relatively simple procedures which can be use mobilize metacarpophalangeal joints of the fingers, affording useful joints, unless there too many other pathological changes.

The poor results of capsulotomy and arthroplasty are due to conditions outside of joint itself, which often can be corrected by associated surgical procedures.

1. BUNNELL, STERLING: Surgery of the Hand. Philadelphia, J. B. Lippincott Co., 1944.

DISCUSSION

DR. STERLING BUNNELL, SAN FRANCISCO, CALIFORNIA: This excellent paper is entirely in confor with my points of view, and with what has been carried out in the nine Army General Hospitals w the work of reconstructing hands has been done. I have reviewed Major Fowler's fine work in repa hands in the Baker General Hospital; I am familiar with his results, and can substantiate his statem

For both capsulotomy, which is really capsulectomy, and arthroplasty of the proximal finger jo there are certain requirements. There must be redundancy of dorsal skin and the surrounding parts r be in good condition. The muscles must be working. The long extensor tendon must be free f adhesions, and there must be a strong flexor. Normally the intrinsic muscles flex these joints; bu combined median and ulnar palsy of these muscles, many patients with their long flexors can flex t joints to a right angle but weakly, though not enough to prevent claw-hand. Therefore, if the interos muscles have been destroyed, we must substitute for them in one of two ways. Either the tendon of flexor sublimis digitorum is transferred to the dorsal lateral band in the finger, or the long flexors given a better angle of approach to the proximal segment of the finger. To obtain this better appro the pulley over the metacarpal head is slit laterally.

The hood over the head of the metacarpal may be of thin deep fascia or of paratenon from over fascia lata. It should prevent the four surrounding tendons from adhering to the head of the metacar Correct muscle balance is also necessary. If upset by angulation forward of the forearm bones, wrist metacarpals, the tightened extensor tendons will not allow the proximal finger joints to flex.

It is essential to maintain this flexion, at first by plaster and then by elastic splinting. Three ty of splints for this purpose have been described elsewhere,—one of plaster and one of metal, each with outrigger over which run rubber bands; and, also, the versatile knuckle bender splint.

ms. A joint space of about one centimeter is obtained, largely at the expense of the proxi-
al phalanx. The metacarpal head is fashioned so that it inclines somewhat volarward, is
pered sharply anteroposteriorly, and is left broad and flat laterally. The phalanx is cut
ansversely. The fine fascia overlying the fascia lata on the anterolateral aspect of the
stal third of the thigh is used as the interposition membrane. It is meticulously inter-
sed between the joint surfaces, beneath the extensor tendon and deep to the tendons of
e interossei. If there has been a loss of intrinsic muscle substance, it is important to
ansfer the flexor digitorum sublimis tendon into the lateral bands of the extensor aponeu-
sis. The shortening of the ray which results from the injury and which is exaggerated
arthroplasty may so weaken the intrinsic muscles that they cannot forcibly flex the
etacarpophalangeal joint. Theoretically, it might be wise to transfer the flexor digitorum

Fig. 3-B

Fig. 3-C

Fig. 3-B: Photographs of hand, showing range of motion in the fingers before operation.
Fig. 3-C: Photographs showing function in hand following arthroplasty.

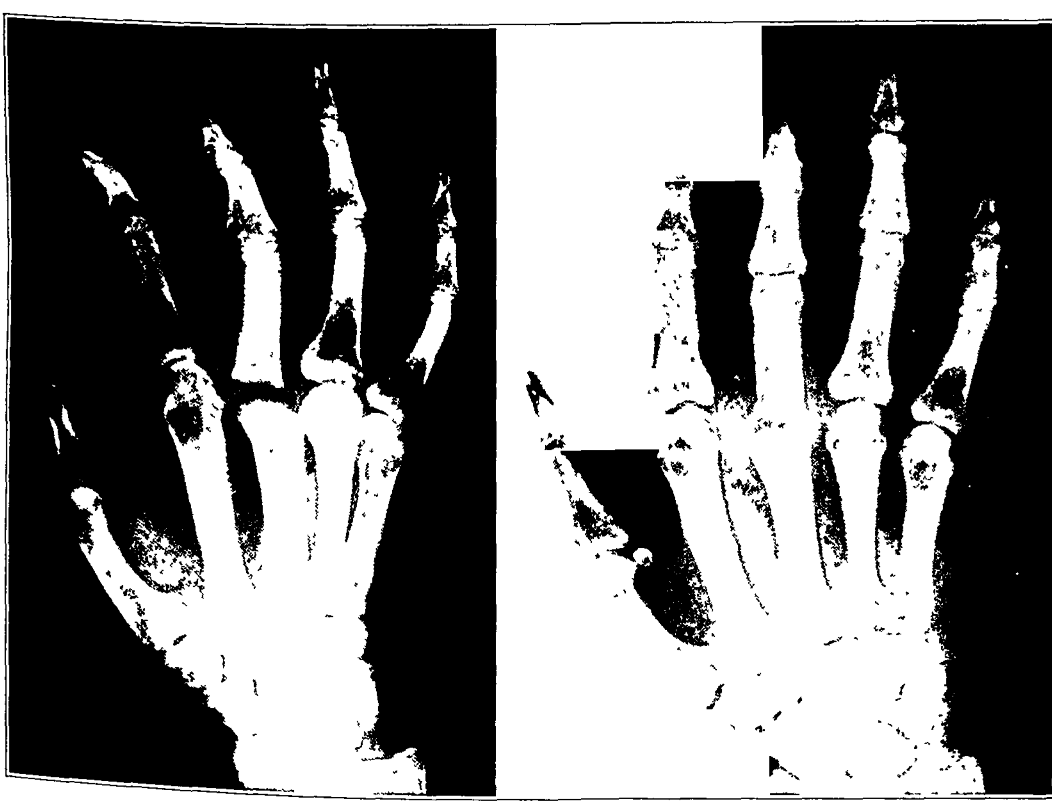

Fig. 3-D

Postoperative roentgenograms, showing arthroplasty of metacarpophalangeal joint of the middle finger.

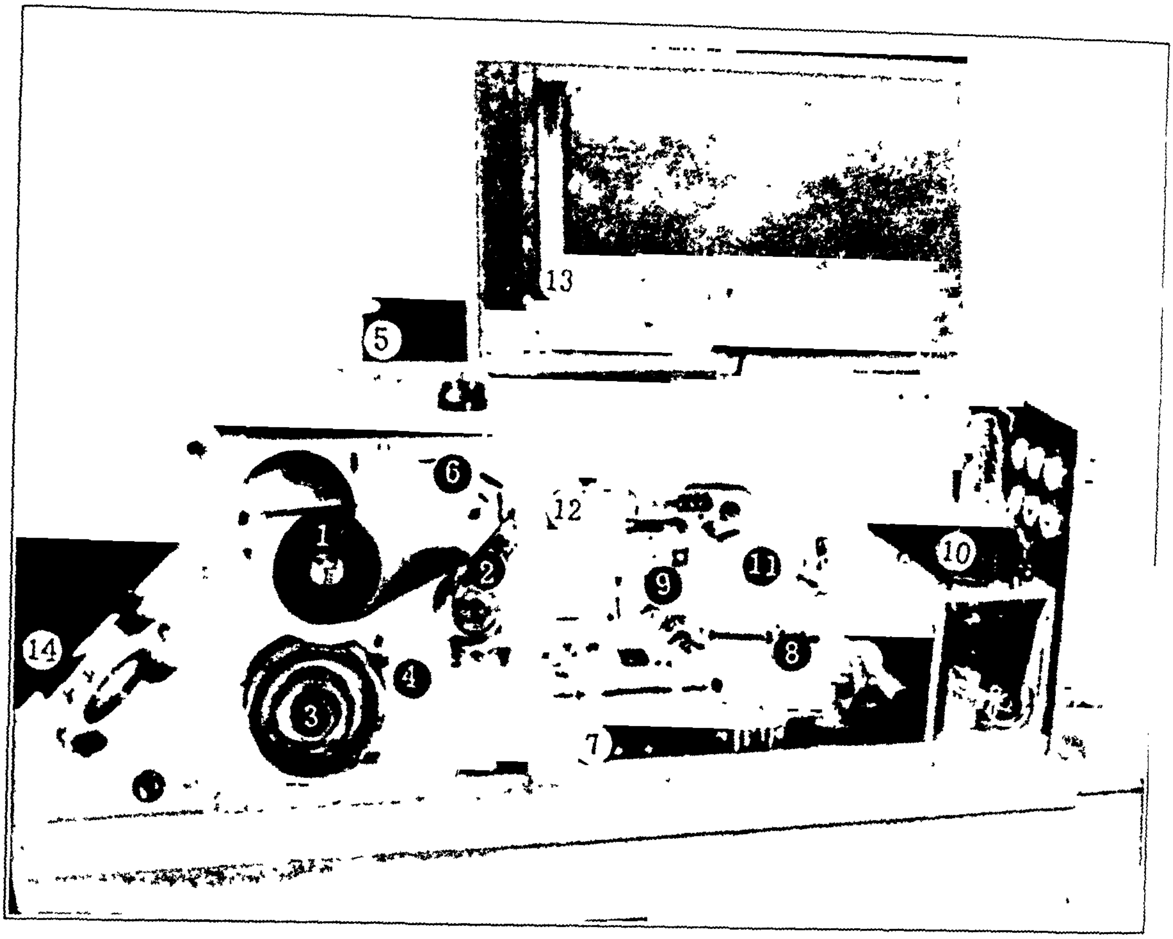

FIG. 1-C

Mechanism of oscillograph.

1: 200-foot roll of recording photographic paper
2: Driving roller
3: Take-up chamber
4: Cut-off knife.
5: Cut-off knife control.
6: Record-numbering projector.
7: Synchronous motor.
8: Timing disc.
9: Magnetic clutch.
10: Galvanometers.
11: Viewing mirror.
12: Prisms and collimating slits.
13: External viewing screen.
14: Control panel.

In 1932 we were mindful of what the most useful records should reveal. On a background of time in seconds and tenths of seconds, there should be recorded the sequence, duration, and amount of pressure, as expressed through the plantar surface of each foot in the act of walking. At that time, however, most earnest efforts failed to provide two essential pieces of equipment,—(1) galvanometers with required characteristics, and (2) material for the construction of pressure discs which had to be precise and uniform in their reaction.

In 1939 an instrument was designed and constructed in the laboratory, which has been in continuous use for recording normal and abnormal locomotion since that time. Provision was made in 1941 for simultaneously recording locomotion and muscle function on the same record.

The instrument is an oscillograph, with independent light sources for each of two sets of six prisms which reflect light to corresponding galvanometers. These galvanometers are electrically connected to six respective areas on the plantar surface of the subject's feet (Fig. 1-A) by a twenty-five-foot flexible cable (Fig. 1-B). Within, the mechanism is operated by a synchronous motor which drives the timing disc and the rollers, which move the two hundred feet of photographic paper at a constant rate of speed. Light beams reflected from the galvanometer mirrors expose the paper through a slit in the camera box. The exposure of the moving photographic paper to the light beam from the swinging

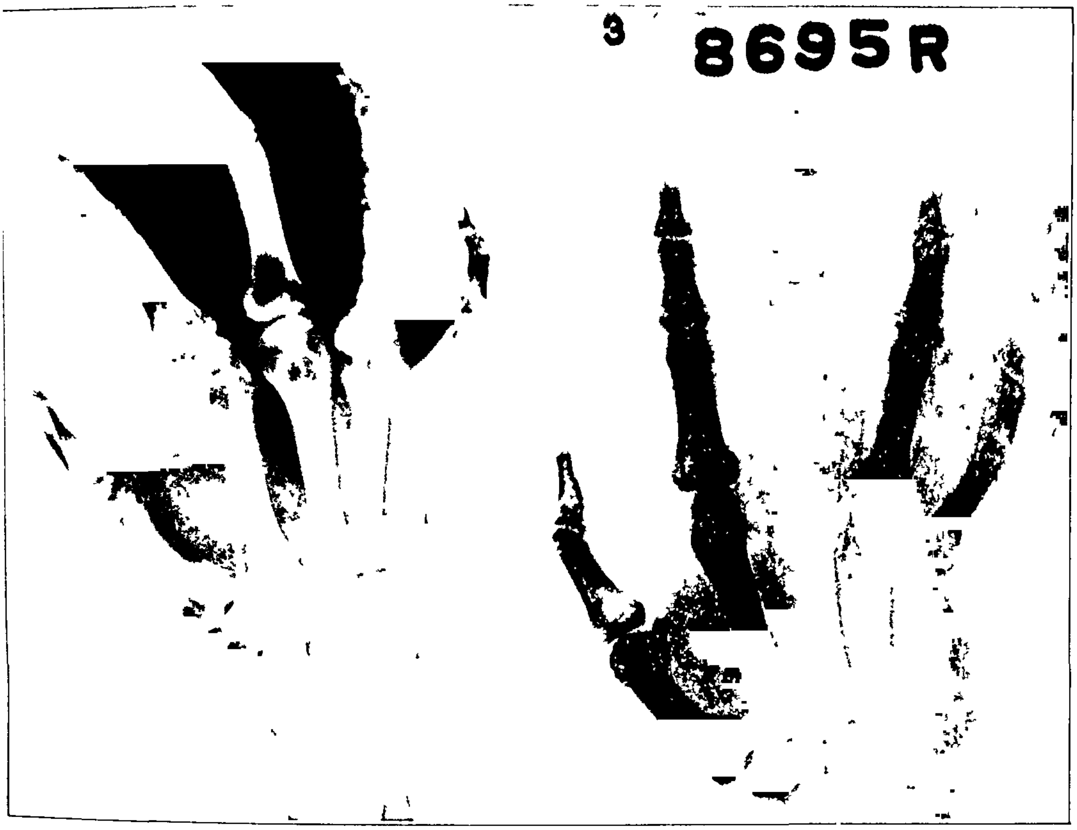

FIG. 4-A
Case W. C. Roentgenograms of hand, upon admission.

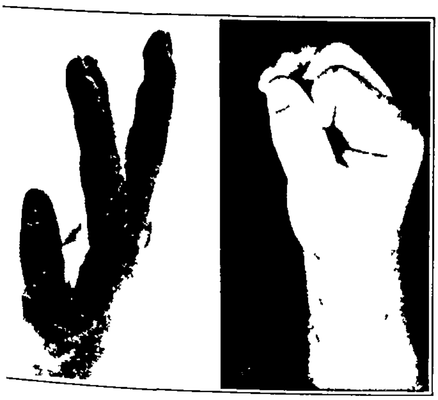

FIG 4-B

FIG. 4-C

Fig 4-B Photographs showing motion in hand before surgery. Active motion in the index and niddle fingers is limited because of the stiff ring finger.
Fig 4-C Photographs showing motion in hand following arthroplasty of the metacarpophalangeal oint of the ring finger and amputation of the little finger.

;ree to which these changes become irreversible depends on the local tissues and their rition. The factors which cause the metacarpophalangeal joints to be held in extension st be carefully evaluated. Splinting of these joints in extension by the surgeon does ur, but it is not generally the predominant factor, for these patients are young, and h immobilization is not often persevered in too long. However, in the presence of tain pathological processes, it may act as the precipitating cause. The most important tor is muscle imbalance, due to paralysis of the intrinsic muscles, or any condition of ensor muscles or tendons which does not allow complete flexion of all the joints of the ger. The lumbricales and interossei are the only muscles which directly flex the meta-pophalangeal joints. When they are functionless, the extensors are not sufficiently posed in their action on this joint; and extension deformity is apt to result, particularly

departure from normal function of the foot can prevail without recorded evidence of the difference. There has been no evidence of unfavorable psychological reactions, when these resources have been used to make clinical records of locomotion.

With the oscillograph in operation, "electrical foot-prints" are photographed upon the record, while the patient walks without instruction as to rate. A record of normal barefoot locomotion is illustrated in Figure 3-A. In Figure 3-B, a *single stance phase* of the right foot has been divided into its three major functional divisions. These respective divisions—reception, support, and propulsion—are revealed by the pressures and duration of weight-bearing on the lateral and medial aspects of the heel, the fifth and third metatarsal heads, the first metatarsal head, and the great toe.

In relation to the end of the third division of the stance phase (propulsion) on the right foot, there is the beginning (reception on the heel) in the stance phase of the left foot. Here we find recorded simultaneous weight-bearing on both feet. This is commonly referred to as the period of double weight-bearing. The functional pattern of the stance phase of the left foot duplicates the corresponding normal functional record of the right foot (Fig. 3-A).

We have found that the day-to-day variations in

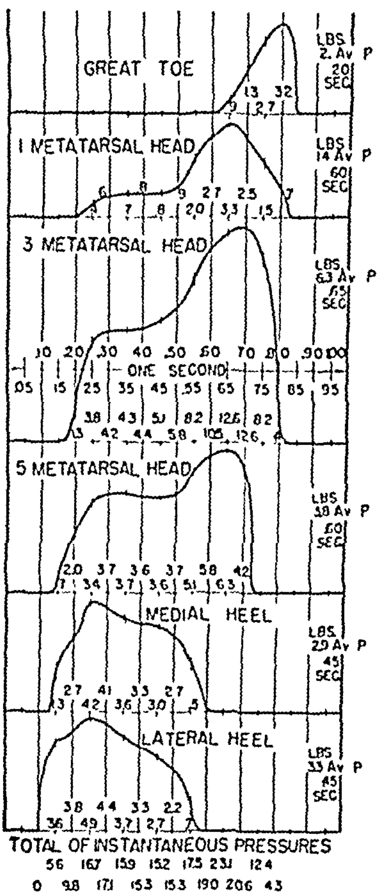

FIG. 4-A

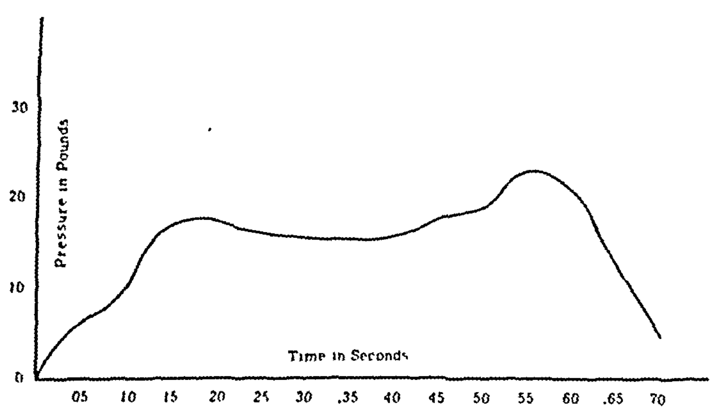

FIG. 4-B

Fig. 4-A: To illustrate the method of measurement, the respective curves were vertically separated from each other without alteration of time interval. Pressures are measured at each 0.05 second intervals for respective curves.

Fig. 4-B: A single line curve for the step shown in Fig. 4-A.

the oscillographic record of the same individual are not great, and this is resolved in the average for the individual. Also, variations between individuals lose their significance in the computation of a group average.

Biological data in general, regardless of the problem or method of measurement, are recognized as subject to wide ranges of individual variations. Differences found in relation to oscillographic records of locomotion fall within a useful range of constancy, as defined by the practical application of biological data in other fields of investigation.

The method of measurement for the quantitative expression of such functional records is illustrated in Figure 4-A. It is accomplished through the use of direct-reading scales. Pressures are measured at each 0.05 second interval for respective curves. Maximum and average pressure values for each of the curves are easily obtained from the tabulation; duration of pressure is read directly from the record.

For the gross comparisons of the function of the foot as a whole, advantage is gained by the use of the single line curve. This is constructed by addition of all pressure values

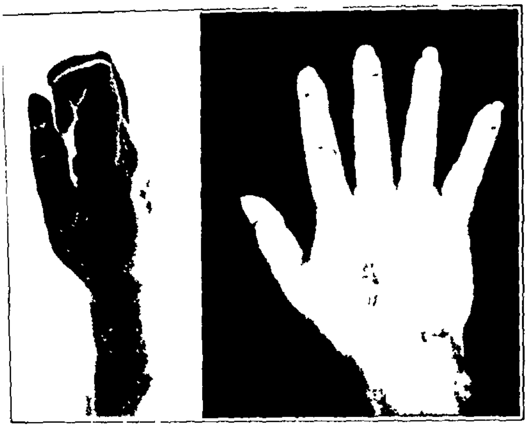

FIG. 6-A

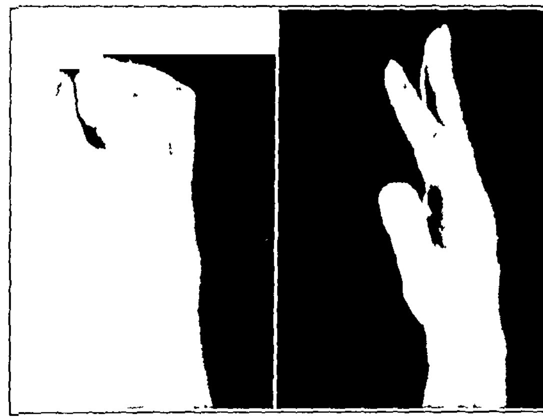

FIG. 6-B

Fig. 6-A: Case J. S. Showing loss of flexion in metacarpophalangeal joints of index and middle fingers.

Fig. 6-B: Showing motion in fingers following capsulotomy of metacarpophalangeal joints and lysis of extensor tendon to the index finger.

n a hand with circulatory insufficiency, for gangrene of the fingers may result. The operaion will not be successful, unless the extensor tendons are free and allow complete flexion. The ankylosis is apt to recur, if muscle imbalance or metacarpal deformity remains.

Technique of Capsulotomy

An incision, about 1.5 centimeters long, is made in the dorsal web on both sides of the affected joint. A one-centimeter longitudinal incision is made in the extensor hood, 0.5 centimeter lateral to the extensor tendon. The anterior part of the extensor hood is then retracted, with the intrinsic tendons and the collateral ligament completely removed. This s done on both sides of the joint, according to the technique of Bunnell[1]. The joint is then flexed by placing the thumb over the dorsum of the base of the proximal phalanx and pushing the phalanx forward and flexing it at the same time. If the interphalangeal joints extend as the metacarpophalangeal joint flexes, it indicates that the extensor tendon is caught in scar tissue and this must be corrected. If the joint opens like a book instead of the phalanx gliding around the metacarpal head, the base of the phalanx is being blocked by an adherent anterior capsule. The joint can hinge open, so that the phalanx is at right angles to the metacarpal; but, unless the base of the phalanx passes around to the anterior portion of the metacarpal head, the deformity will certainly recur. The adherent anterior

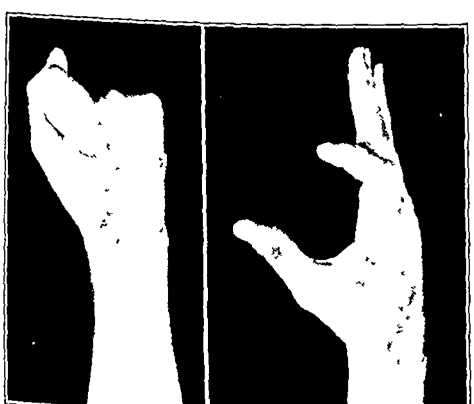

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case J. P. Photographs showing loss of flexion in metacarpophalangeal joint and loss of extension in interphalangeal joints of index finger, following old, compound fracture of second metacarpal with destruction of intrinsic muscles to index finger.

Fig. 7-B: Showing function in index finger following capsulotomy of the metacarpophalangeal joint and transfer of flexor digitorum sublimis tendon to extensor aponeurosis.

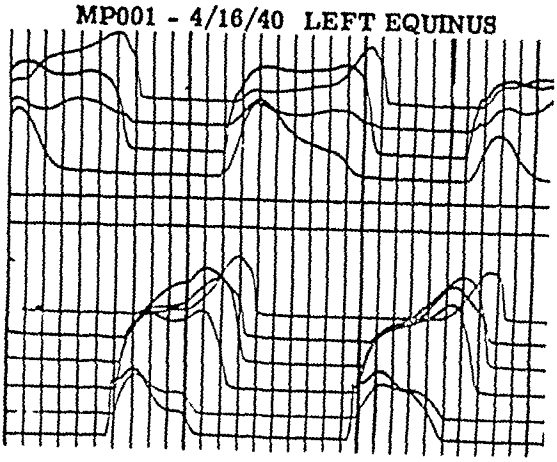

FIG. 6-A
No pressure on left heel.

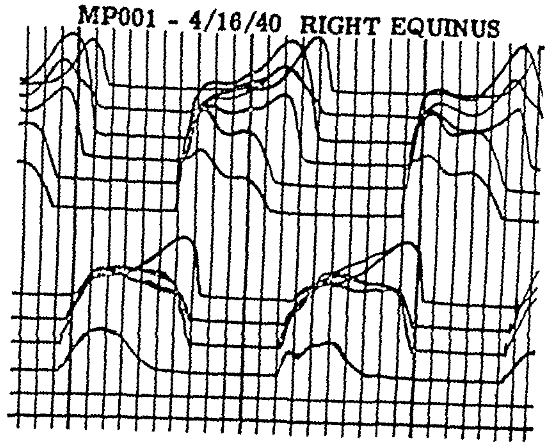

FIG. 6-B
No pressure on right heel.

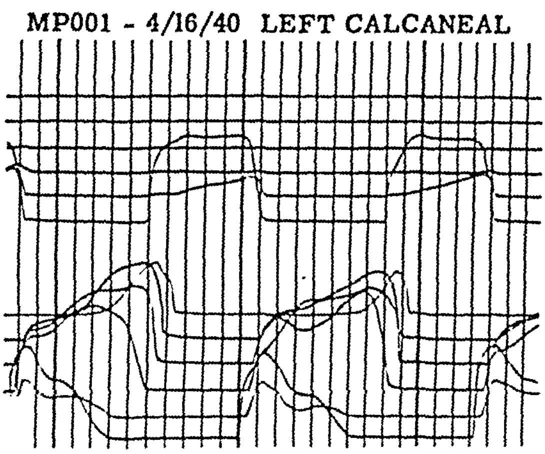

FIG. 6-C
No pressure on left medial heel and fore rt of foot.

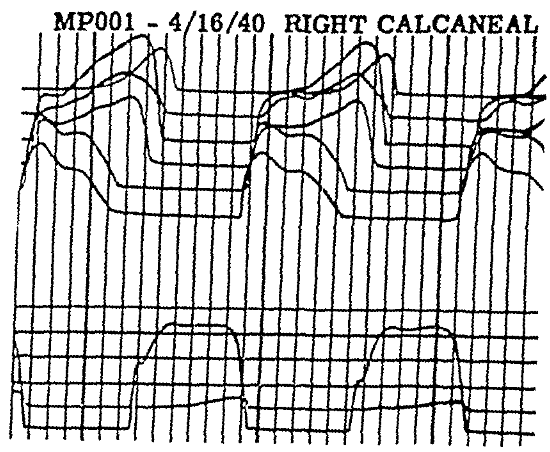

FIG. 6-D
No pressure on right medial heel and fore part of foot.

NOTE: Functional compensations required on "normal" side represent gross departures from normal function in each instance.

is common to all others in walking from place to place. For these reasons, we have found differences in the records of normal individuals. But the characteristics common to all dominate, and the individual characteristics are eliminated when the records of a large number of normal subjects are reduced to a single curve.

This fact was revealed by the following procedure. The records of eighty-seven nurses were divided into various groups on the basis of age, weight, height, rate of walking, and pronation. This was done for the purpose of determining which of these factors gave significant evidence of a dominant influence, and to determine the base line against which all records, normal and abnormal, could be compared. We have found that the rate of walking has a significant effect upon the pattern of the curves in the stance phase of the step. As yet we have been unable to fully explore for similar groupings on the basis of age, weight, height, and pronation.

The influence of rate of walking is revealed in Figure 5-A. The eighty-seven records were divided into five groups on the basis of the average duration of the stance phase in each record,—that is, the rate of walking. The method of measurement previously described was used, and the results in each of these groups are represented by a single curve. These respective curves express the total amount of pressure exerted through all of the respective pressure discs at successive time intervals during the stance phase of the step. The variations due to rate of walking are quite evident.

In Figure 5-B the measurements for respective groups were statistically reduced to a

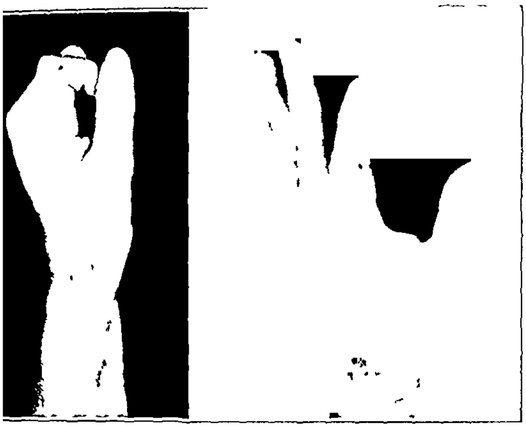

Fig. 9-B

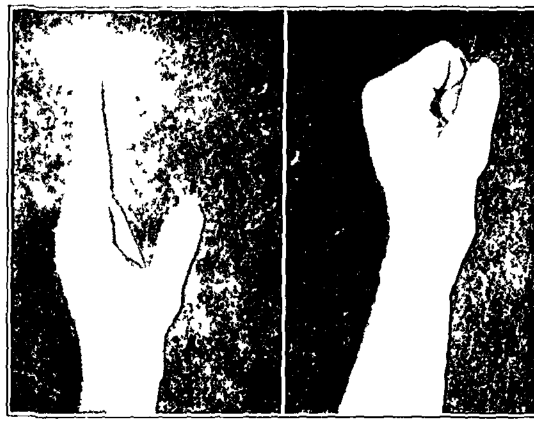

Fig. 9-C

Fig. 9-B: Photographs showing function in hand with ununited fracture of second metacarpal and stiff metacarpophalangeal joint.
Fig. 9-C: Photographs showing function in index finger following bone graft to second metacarpal and capsulotomy of the metacarpophalangeal joint.

Fig. 9-D
Roentgenograms of hand following bone graft to the second metacarpal.

int, because of pain or undue swelling, a traction cast is reapplied at the earliest oppor-ıity, and correction is gradually obtained. Full correction is maintained for three weeks; ı a removable traction splint is applied, which is worn for about one month and re-ved gradually. It is reapplied if there is a tendency to recurrence of the deformity.

sults

The results from capsulotomy are excellent, and 80 to 90 degrees of motion may be ᶜdently expected, if local tissues are good and the mechanics of the hand are satis-tory. Over 100 capsulotomies have been done, mostly in conjunction with other opera-ns. The associated pathological conditions have been such that meticulous tabulation

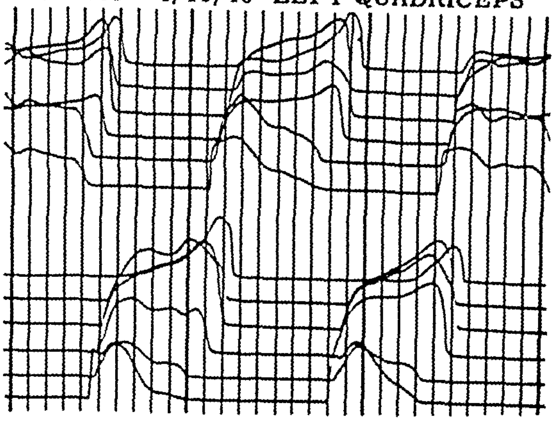

FIG. 8-A

Duration of stance phase longer on the left. Gross departure from normal curves bilaterally.

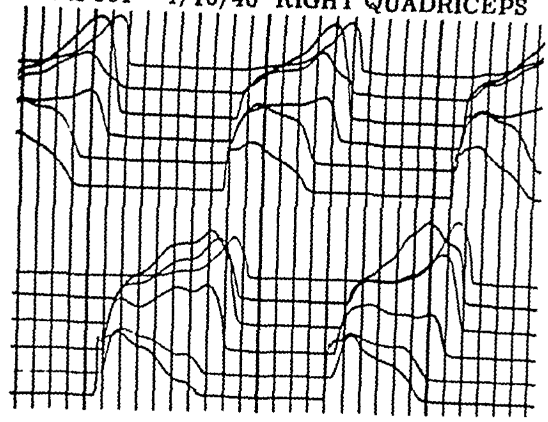

FIG. 8-B

Curves of right foot are essentially a mirror image of those for left foot (Fig. 8-A).

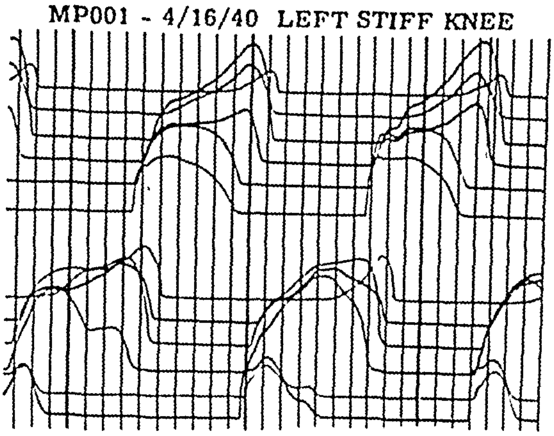

FIG. 8-C

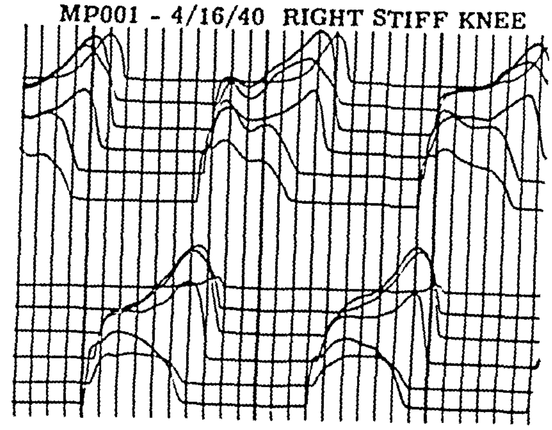

FIG. 8-D

Same characteristics in curves of left and right foot on respective records. Gross differences in compensatory function by left and right feet in respective records.

in locomotion, there is an expression of values very different from those which fall within the limits of normal function. This fact fosters further confidence in the quantitative definition of normal human locomotion, as previously presented.

It is not our purpose, within the scope of this paper, to discuss the details of recorded disabilities. However, the potential significance of information pertaining to normal locomotion may be indicated by a brief reference to the manner in which the records of disabilities differ from those of normal locomotion.

In Figure 6-A, a left equinus gait produced a record free from weight-bearing on either medial or lateral aspects of the left heel. The increased work done by the fore part of the left foot is indicated by the longer duration of the stance phase (slower rate) and the increased height of respective curves, particularly at the third metatarsal level. Essentially the same characteristics prevail in the record of a right equinus gait (Fig. 6-B).

A left calcaneal gait is illustrated in Figure 6-C. The weight is borne primarily on the lateral aspect of the left heel. In Figure 6-D, the record of a right calcaneal limp is essentially identical to that in Figure 6-C, the continuously straight base lines corresponding to the first metatarsal head and great toe.

Figure 7-A reveals the absence of pressure on these levels in a left varus limp. The lateral heel and fifth metatarsal curves are higher and longer; the medial heel and third metatarsal curves are lower than normal. In the record shown in Figure 7-B, there are revealed the characteristics of a more exaggerated varus limp of the right foot. Here there is omission of weight-bearing on medial heel, first metatarsal head, and great toe. The major

THE DEFINITION OF HUMAN LOCOMOTION ON THE BASIS OF MEASUREMENT

With Description of Oscillographic Method * †

BY R. PLATO SCHWARTZ, M.D., AND ARTHUR L. HEATH, B.S., ROCHESTER, NEW YORK

From the Department of Surgery, Division of Orthopaedics, University of Rochester, School of Medicine and Dentistry, Rochester

The importance of normal locomotion to the physical and economic advantage of ery individual is self-evident. The significance of human locomotion to orthopaedic rgery is found in that large percentage of patients who require treatment to prevent sabilities in the function of walking.

In previous papers[8,9,10], we have presented a review of the literature on this subject. i the relatively few references, some of which must be regarded as classics[1,2,5,6,7], there as none which could be applied to clinical problems. Work done in the past did not ovide the means for a quantitative definition of normal human locomotion; therefore, inctional disabilities and the results of treatment could be recorded only in words and various methods of illustration.

Fig. 1-A

Six pressure-sensitive discs are applied to respective levels on the plantar surface of each foot.

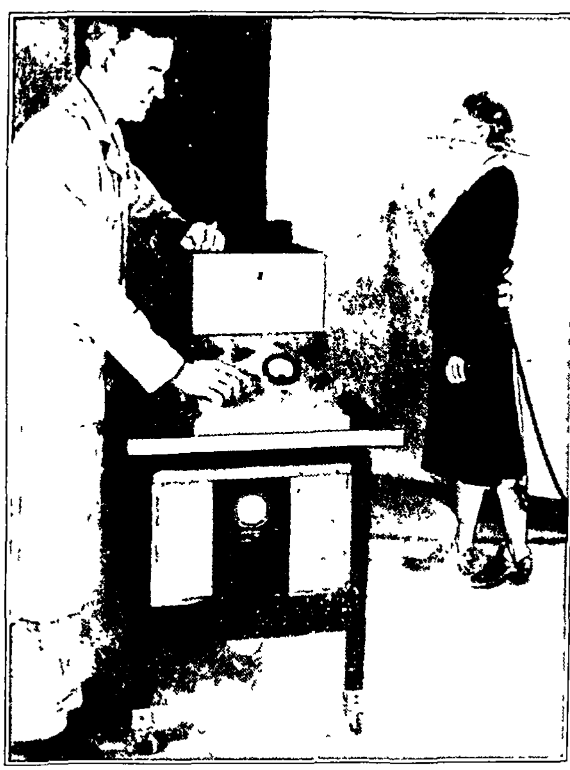

Fig. 1-B

Subject, oscillograph, and operator. Records are made with the subject either wearing shoes or barefoot.

The nature of the problem has defined the narrow limits within which a combination particular resources can be made to provide records, from which human locomotion n be reduced to measurement. This has been repeatedly emphasized in the successive orts which we have made since 1926. It is these exacting requirements which have layed the development of the present resources for a period of eight years.

* Aided by a grant from the National Foundation for Infantile Paralysis, Inc.

† Read before the Meeting of The American Orthopaedic Association, Hot Springs, Virginia, ne 27, 1946.

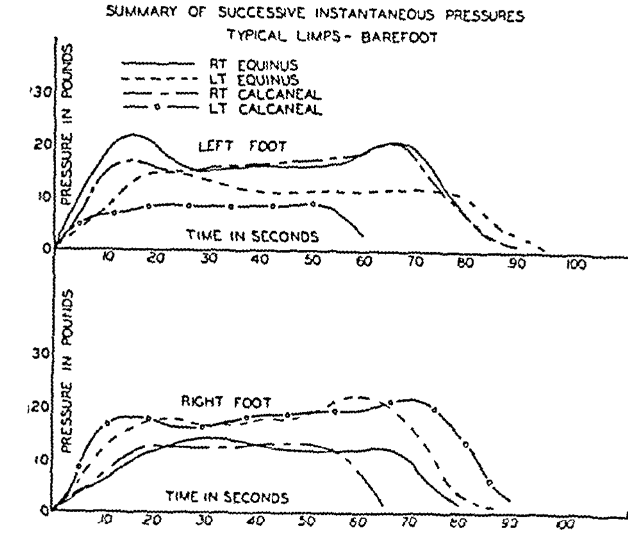

Fig. 10-A

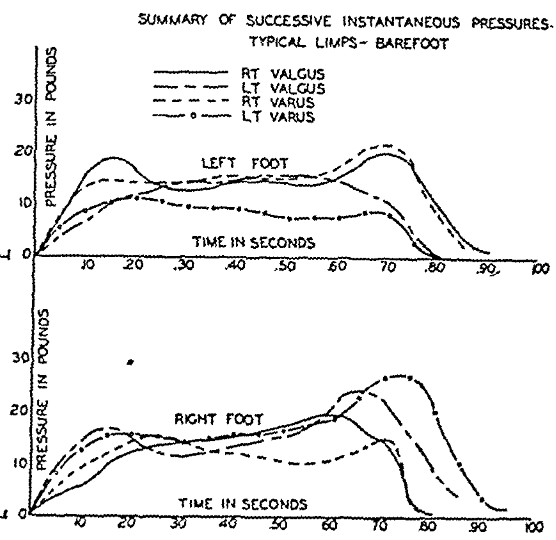

Fig. 10-B

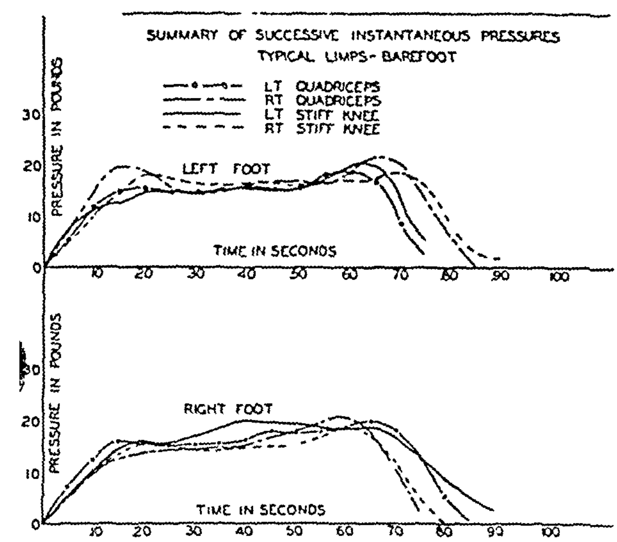

Fig. 10-C

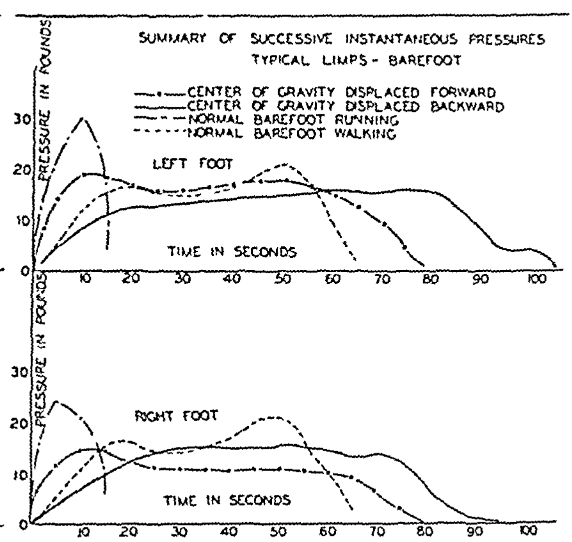

Fig. 10-D

backward (Fig. 9-B). In running (Fig. 9-C), the duration of the stance phase is reduced to 0.15 second ($\pm$ 0.7 sec. for normal walking) without any weight on the heel. Foot function is limited to the respective levels of the fore part of the foot, including the great toe. The record of normal barefoot walking (Fig. 3-A) is here repeated (Fig. 9-D), for ease of comparison with the records of abnormal limps.

In Figures 10-A, 10-B, 10-C, and 10-D, the respective records of functional disabilities have been reduced to single curves for respective feet. Such disabilities are characterized by the manner in which they alter the duration of the stance phase on the respective affected and normal extremities. For this reason, the records of functional disabilities should not be reduced to the 0.65 second for the duration of the stance phase of the step.

In all of these single curves of functional disabilities, it will be noted that the duration of the stance phase is significantly greater than normal, and that the curves are grossly different. This may be accepted as an index of our experience since 1940. From this we conclude that the variations within the limits of normal locomotion cannot produce a record characteristic of any significant functional disability.

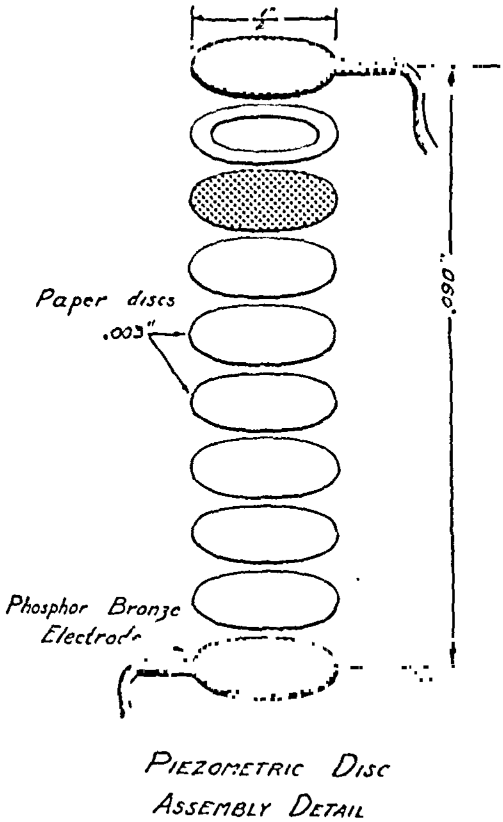

FIG. 2-A

Arrangement of carbon discs in construction of piezometric (pressure-sensitive) disc.

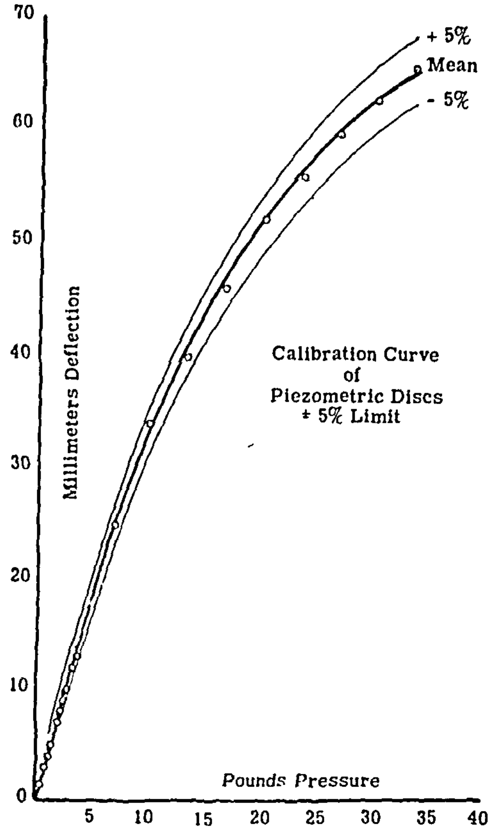

FIG. 2-B

Each piezometric disc is made to conform to this calibration curve.

mirror causes a curve to be photographed upon it. Each successive record is photographically numbered and a light-tight take-up chamber is provided for removal of exposed paper (Fig. 1-C).

The pressure-sensitive discs are constructed as indicated in Figure 2-A. All twelve discs are made and calibrated to react uniformly to successive amounts of pressure as in the distribution curve (Fig. 2-B). They are applied to the respective areas on the plantar surface of each foot, as in Figure 1-A, and effectively secured with Scotch tape. These areas were not arbitrarily selected; by extensive tests they were found to produce the most valid records of the stance phase of normal locomotion. Moreover, it has been found that no significant

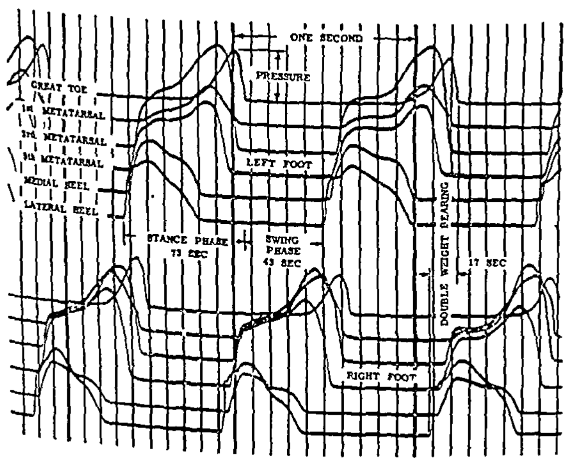

FIG. 3-A

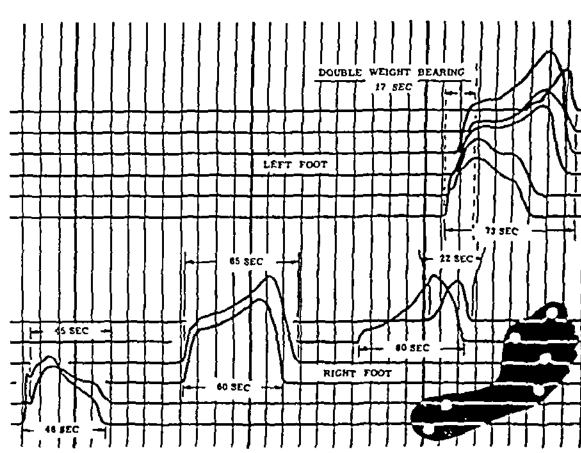

FIG. 3-B

Fig. 3-A: This record of "normal" barefoot locomotion on a background of time in seconds and tenths of seconds illustrates the source of measurements.

Fig. 3-B: This illustration is a break-down from Fig. 3-A to provide a better understanding of Fig. 3-A.

variations on the sole of the foot, due to gait. Having established the normal, he is now beginning, as he has shown, to study abnormal gaits; and this offers an absolutely inexhaustible field for investigations with its analyses of the functional, as well as of the anatomical, disabilities arising from muscle imbalance and joint restrictions.

I certainly want to congratulate him on his tenacity, ingenuity, and ability for critical analysis. I also want to sympathize with him in the prospect of the tremendous volume of problems which this method puts in his lap for solution.

Dr. Arthur Steindler, Iowa City, Iowa: I always have had the greatest admiration for Dr. Schwartz's achievements in this very difficult line of observation of the human gait. In order that we may understand how it fits into long studies of human gait, we will have to realize that this represents a most ingenious, simplified method of measuring counterpressure by direct observation. That was the thing that Braune and Fischer failed to develop. For this reason, they had to follow a circuitous route of observing pressure by calculating the derivatives from path curves, to velocity curves, and to the curve of acceleration, which obviously will give the force, because acceleration is a function of the force. It took Braune and Fischer eight hours to dress their subject, in order to demonstrate with Geisler tubes the path curves alone. In order to bring about a determination of those horizontal components of the pressure curve, we are now in possession of enough information to calculate the horizontal components, as the heel is being put on the ground, as well as the strength of propulsion and restraint in the terms of this resultant component during the standing phase. The development of Dr. Schwartz's method has marked a tremendous advance in our ability to measure the force directly. The problem now is opened to the general benefit of the profession. It finally has become something that the orthopaedic surgeon can tackle.

Dr. Schwartz (closing): It has been our continuous desire to develop a method of recording locomotion that would have some potentially clinical usefulness. At present, it seems to us that we have accomplished this objective and reduced the method to a relatively simple procedure.

It is true that we do not measure total pressures. It is also true that total pressure has not been our aim. We feel that we have briefly given you the results that provide an index of the normal pattern of human gait.

Granted, there are individual characteristics of locomotion. One of the reasons for potential discouragement in the beginning was the oft-repeated statement that "there was no use in doing this work because everyone walks differently".

Such objection was not valid. Everyone has a common pattern of locomotion on which individual characteristics are superimposed. We have recorded and given quantitative expression of the common pattern.

I am duly grateful for the time and consideration which were given to this paper by Dr. Inman, Dr. Johnson, and Dr. Steindler, as indicated in their respective discussions.

which occur simultaneously within the 0.05 second intervals from the beginning to the end of the stance phase of the step. These successive values are shown at the bottom of Figure 4-A,—that is, the total of instantaneous pressures.

When plotted on a graph, with the same time base as in Figure 4-A, the resulting single curve represents the summation of pressures common to the foot during the stance phase of the step. By thus resolving all functional details of the six most significant levels of the foot into a single curve, the most graphic quantitative comparison of variations in foot function is achieved (Figs. 10-A, 10-B, 10-C, and 10-D).

In Figure 3-B the duration of contact of the respective levels of the right foot with the floor is indicated. This is summarized in Figure 4-A. The period of double weight-bearing (Fig. 3-A) is 0.17 second, in which time interval the entire plantar surface of the left foot, not including the great toe, was in contact with the floor. This period of double weight-bearing is constant for normal individuals when walking at the average rate of two steps per second. The duration of double weight-bearing lengthens as the rate drops, shortens as the rate increases, and is absent in running (Fig. 9-C).

The swing phase of the step,—that is, from the time the right or left great toe leaves the floor until the right or left heel contacts the floor, is ± 0.5 second, as illustrated in Figure 3-A (0.43 sec.). The stance phase of the step is ± 0.7 second, 0.2 second longer than the swing phase.

All records of normal locomotion have essentially equal duration of time for the stance phase, double weight-bearing, and swing phase of the step for right and left foot, respectively. Any significant inequality of time interval for one or more of these recorded values is characteristic of a limp, and is accompanied by departure from the pressure curves which are typical of normal function.

It is common knowledge that an individual may be recognized by the sound of his footsteps. This means that each individual walks differently. However, it follows that all normal individuals superimpose their slight differences upon a functional expression which

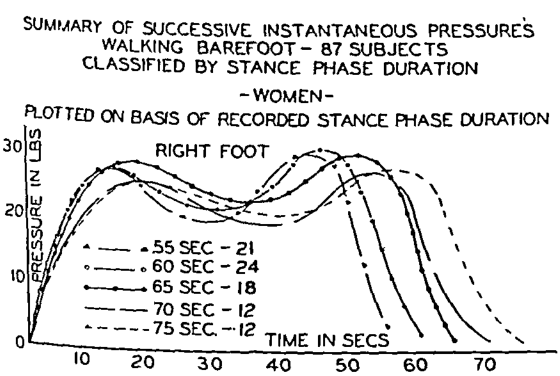

FIG. 5-A

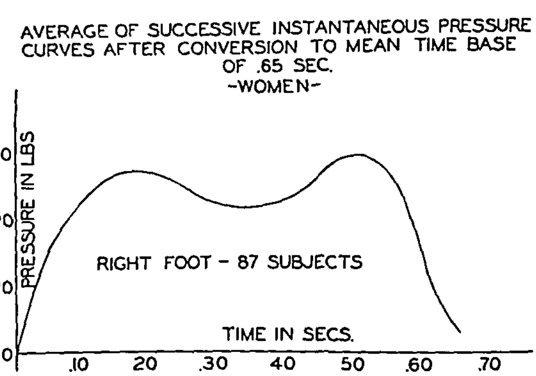

FIG. 5-C

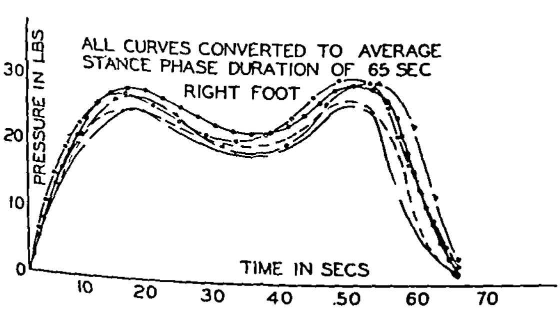

FIG. 5-B

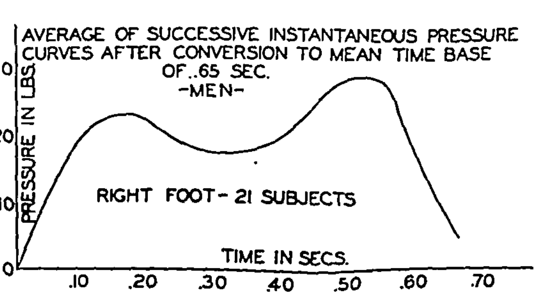

FIG. 5-D

Fig. 5-A: Curves representing the single line analysis of eighty-seven nurses.
Fig. 5-B: After the curves in Fig. 5-A were statistically converted to the standard time base of 0.65 second.
Fig. 5-C: The average pressure flow for the foot as a whole, for the entire group.
Fig. 5-D: Average curve for a group of male subjects resulting from the same method.

This was an especially acute problem in the Territory at that time, for two reasons: First, in stevedoring, the laws, both federal and territorial, make no provision for compromise settlements in case of unapportionable disability arising from a pre-existing condition, such as hemivertebra or hypertrophic changes associated with sprain of the back. One such case has been carried by the company for more than four years. In other words, the company is responsible for care of the man. Second, the recently invalidated martial law likewise prevented the man from leaving his job, so that only death, the doctor, or crime could part him from his employer. It was, therefore, unwise to hire a man who might prove to be a liability, and equally unwise for the employee to try work for which he might prove unfit.

Backache was also a problem at the Navy Yard, among the civilian employees and other contract workers. Thousands of Caucasian and Negro workers were employed by defense contractors and at the Navy Yard; all of them were supposed to have had pre-employment examinations, but these must have been cursory.

The stevedore applicants were largely local men in their early thirties; two-thirds were Filipinos, a seventh were Japanese, and a fifth were of mixed races. These local residents had their own homes or boarding houses, and friends; and they ate their accustomed foods as far as possible. The individuals of a similar average age who had come from the mainland were strangers in a strange land, ill-housed, uncongenially quartered, poorly fed, separated from home and loved ones by censorship, irregular and slow communications, and lack of travel facilities; frequently they had no friend to whom to talk. Both groups were subject to the sunset-to-sunrise curfew and a strict blackout; they were restricted as to movement; entertainment was non-existent; the choice of food was limited; and all were "frozen" to their jobs. All these inconveniences bred unhappiness and ills.

Largely from these two groups, during the past four years the author has examined 560 persons with backache; 470 were men and 90 were women. During the first year, it was noted that roentgenograms of the back showed abnormalities in all but about 5 per cent. of the indviduals with backache. A program of pre-employment examinations was instituted for the stevedores of Castle and Cooke Terminals on April 23, 1943, and consisted of obtaining anteroposterior and lateral roentgenograms of the lumbosacral junction of all applicants. In the following three years, 1049 applicants for stevedoring were examined. A similar examination was made of 131 men, employed as stevedores before April 23, 1943, who complained of chronic backache. The group of private patients with backache, the complaining stevedores who had not had an examination of the back, and those who had had pre-employment examinations form three groups, each of which will be scrutinized; comparisons will be made when possible. The "old" employees were those employed prior to April 23, 1943.

In order that the appraisal should be fair, it was essential that the orthopaedic surgeon be acquainted with the nature of the work required of the men. Equipped with military passes and accompanied by the proper officials, the author inspected stevedoring operations of all kinds; the physical demands made on the men were appraised, as well as the types of cargo and the methods of handling it.

Cargo brought to the side of the ship by mechanical means must be hoisted or conveyed aboard and then lowered into the hold, either directly or by chutes. Up to this

TABLE I*

	1941	1942	1944	1945
Number of backaches	76	71	37	85
Total number of days lost	908	871	272	188
Average number of days lost per patient	11.95	12.25	7.35	2.2

* Figures supplied by Castle and Cooke Terminals, Ltd.

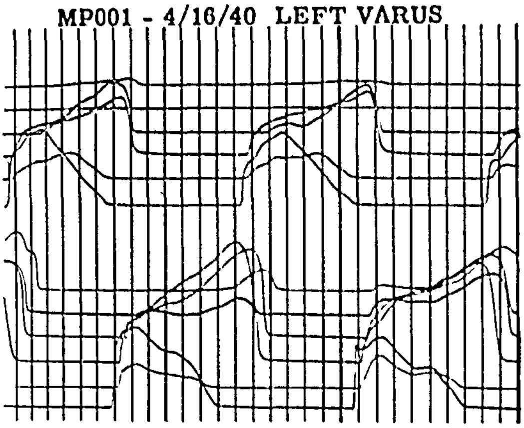

Fig. 7-A

Function absent on left medial heel, the first metatarsal head, and great toe.

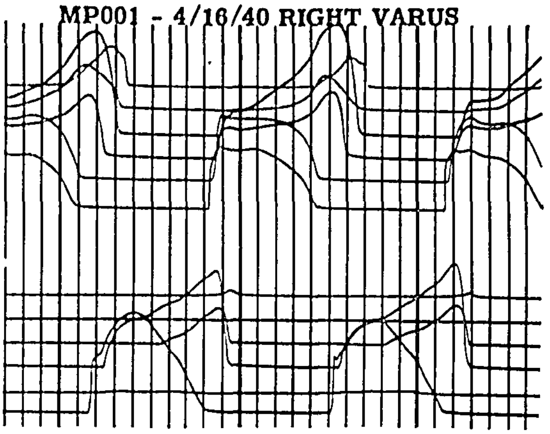

Fig. 7-B

Function absent on right medial heel, the first metatarsal head, and great toe.

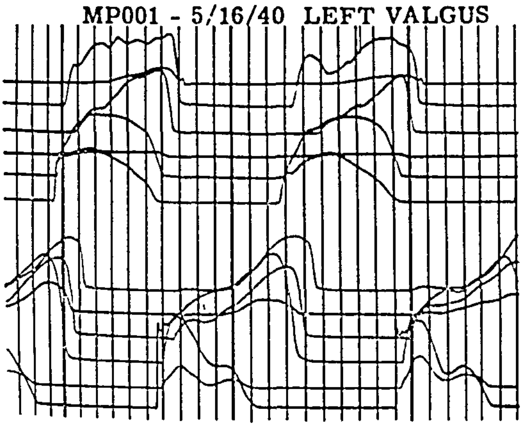

Fig. 7-C

Function absent on left fifth metatarsal head and great toe.

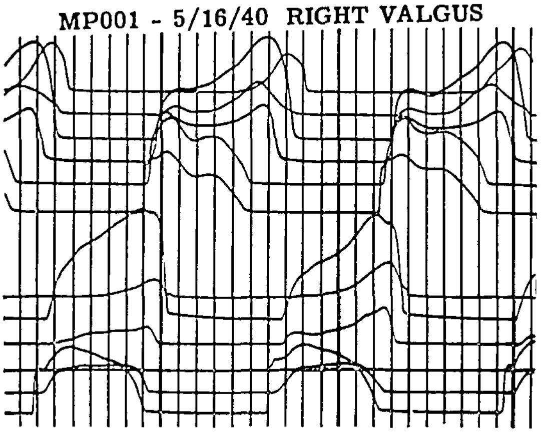

Fig. 7-D

Function absent on right fifth metatarsal head and great toe.

Note: Absence of function on one or more levels is accompanied by greater function on other levels of the same foot.

common duration for the average stance phase of the step,—that is, 0.65 second. It is evident that the removal of the variable in this instance was accompanied by a greater similarity in the curves representing respective groups. Here we have expressed a fair example of the high-limit and low-limit characteristics which are common to the single curve for normal locomotion. At present it is felt that a single curve, expressed in terms of 0.65 second for the duration of the stance phase, is the most reliable expression of normal locomotion.

The single curve (Fig. 5-C) represents the average of the five curves in Figure 5-B. Figure 5-D represents a similar analysis of records of twenty-one men.

The evidence thus far presented does emphasize the fact that human locomotion is a very complex function. Although it is normally expressed with ease, its simplicity is denied by any serious effort to quantitatively define its characteristics. Concurrent with such an effort, there is fostered a respect for the many factors which simultaneously prevail in varying degrees and, therefore, constitute variables which must be given due consideration.

In arriving at the quantitative definition of the normal characteristics of barefoot locomotion, we feel that the method of recording can be accepted as reliable. We are equally confident that the simple method of measurement of the records is free from significant errors in reducing (1) the rate to a common stance phase of 0.65 second, and (2) the respective six curves for each foot to a single curve.

When this identical procedure is applied to the quantitative evaluation of disabilities

which no back examinations were made. In 1944 and 1945, all stevedores were examined. Each period included one full year and one partial year of war; otherwise the factors were alike. The figures for 1945 are more complete than those for the other years, and reveal several other bits of information. Of the 850 stevedores employed by Castle and Cooke in the latter part of 1945, 612 had been employed without back examinations and 238 had had pre-employment examinations, indicating a wide marginal turnover among stevedores.

The most significant finding in respect to the causes of backache among stevedores lies in the fact that 62 (73 per cent.) of the total of eighty-five backaches in 1945 appeared in the atraumatic group. Of these, forty-four (71 per cent.) developed while the men were working with special, or repetitive, cargo.

Observations concerning treatment and disability are summarized in Table II. The significant findings are the greater number of repeaters in the unexamined group and the greater amount of time lost per backache in this group.

The efficiency of the ratings may perhaps be gauged by the fact that, of the examined group complaining of backache, five had been rated as good and eight as fair. The one poor risk, who had been employed through an error, appears in the backache group.

It would therefore appear that, by pre-employment roentgenographic examinations of stevedores, (1) 30 per cent. of applicants have been eliminated as unfit for this work; (2) the time lost as a result of backaches has dropped by 82 per cent.; and (3) the compensation paid has fallen from about 375 days in the first two years to thirteen days in the last two years.

No objection to this plan of examination has been received from the employees or the labor union; their attitude is rather that of cooperation and appreciation, for they feel that the present system is designed for their protection. This is due largely to the way the problem has been handled by Castle and Cooke's Personnel Department. Each man rejected has had the reason for his rejection discussed with him by a member of the Personnel Department, who has been instructed in the meaning of the various terms appearing in the reports. Each person rejected may consult the author without cost. He is shown his roentgenograms, and the difficulty is explained. A number of persons with correctable conditions have had surgery. All have seemed grateful. One or two with spondylolisthesis, who gave no history of backache, were not reconciled to non-employment as stevedores, because they needed the "big money" ($1.00 per hour).

The medical study should be prefaced by two observations:

1. In a person complaining of backache, an examination during a symptom-free interval is nearly useless.

2. Except in a few conditions, such as fractures and destructive disease of the vertebrae, a roentgenographic examination does not prove that a particular finding is the cause of a specific backache. This is difficult enough with the patient and his roentgenograms lying side by side.

CLINICAL FINDINGS

Concerning these studies, medical men might be interested in several points:

1. Among the private patients, the distribution of the backaches was as follows:

TABLE III

CONGENITAL AND ACQUIRED DEFECTS IN THREE GROUPS OF PATIENTS

	Private Patients (*Per Cent.*)		Old Employees (*Per Cent.*)		Pre-Employment Group (*Per Cent.*)	
No defects	5.3		13.7		18.8	
Congenital anomalies alone	21.9	58.4	13.7	58.7	19.9	51.8
Combined congenital and acquired defects	36.5	72.8	45.0	72.4	31.9	61.2
Acquired defects alone	36.3		27.4		29.3	

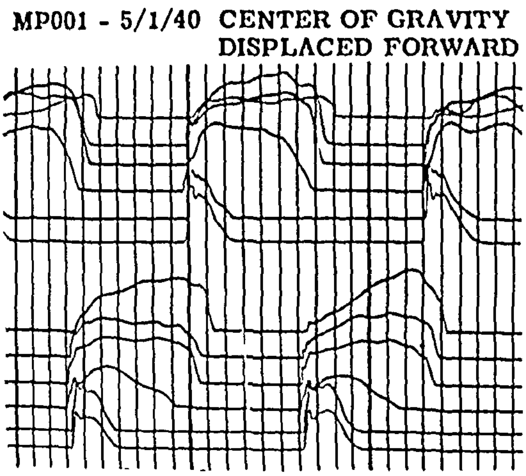

FIG. 9-A

Minimum function on heels, maximum function on fore part of the foot; duration of stance phase lengthened.

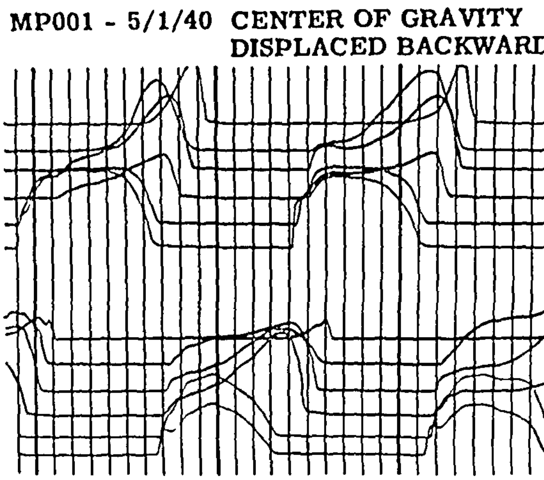

FIG. 9-B

Maximum function on heels, minimum function on fore part of foot; duration of stance phase lengthened.

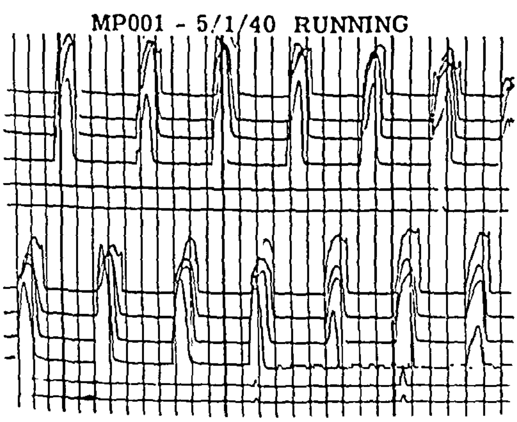

FIG. 9-C

Stance phase shortened to $\pm$ 0.15 second, without heels participating; $\pm$ 0.1 second between contact of respective feet.

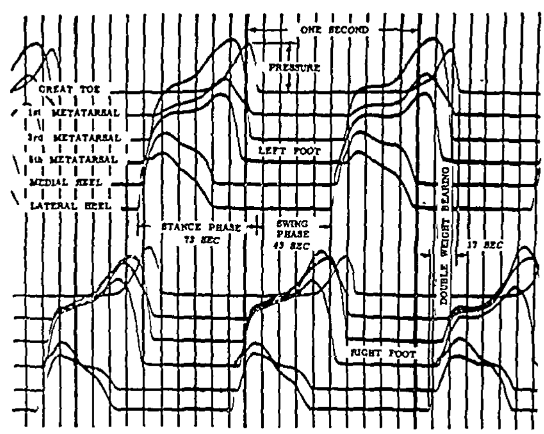

FIG. 9-D

Record of normal walking for comparison.

weight is borne on lateral-heel and fifth-metatarsal levels, with only a small share carried by the third metatarsal.

The recorded characteristics of a valgus limp are revealed in Figures 7-C and 7-D, left and right foot, respectively. The most exaggerated deformity is expressed in the functional deficiencies recorded in Figure 7-C. Partial or total absence of weight-bearing at the levels of the fifth and third metatarsals and great toe, with grossly elevated first-metatarsal curve, is characteristic.

The quadriceps limps recorded in Figures 8-A and 8-B, left and right foot, respectively, show significant function on all six levels of respective feet, low and abnormal distribution of pressures on heel and first-metatarsal levels, high and abnormal distribution of pressures on the other three levels.

The records of left and right stiff-knee limps (Figs. 8-C and 8-D) show a lessening of great-toe function on the affected side, and emphasize the functional adaptation required of the normal extremity to compensate for the functional disability expressed in a fully extended stiff knee.

With marked forward displacement of the center of gravity while walking (Fig. 9-A), a minimum of normal foot function is expressed through the heels, the fore part of the foot and great toes doing the work. These functional expressions through respective levels of the foot are essentially reversed, when the center of gravity is correspondingly displaced

TABLE VII

HYPERTROPHIC CHANGES

	Group Examined Before Employment (*Per Cent.*)	Private Patients (*Per Cent.*)	Old Employees (*Per Cent.*)
One location	69.0	69.0	56.0
Two locations	24.1	25.5	33.0
Three locations	6.8	5.4	11.0

backaches in persons having these conditions, or both. In any event, the appearance of such conditions should discourage the employment of an individual for heavy labor.

5. Three conditions were studied to see if their frequency of occurrence dropped in the non-stevedore group with backache, but increased in the group doing heavy labor (Table VI). The *significance of the observations is not altogether clear. Spina bifida* occulta appeared so frequently as a secondary finding among the major causes of backache, listed previously, that its increase was probably of no special significance, but rather something left over after the hard labor had tended to eliminate those individuals having major causes of back disability. The author considers spondylolysis as a potential source of spondylolisthesis, and distinctly a backache hazard, which is brought into prominence by heavy labor.

6. Since hypertrophic changes are likely to occur in numerous places in the same individual, the statistical evidence as to the importance of multiple appearances was considered. Hypertrophic changes have been placed in three anatomical and physiological groups: (a) the longitudinal ligaments, (b) the iliolumbar ligaments, and (c) the sacro-iliac ligaments. Several intervertebral spaces might show changes, but they would all be grouped as one, under longitudinal ligamentous changes. Therefore, we are limited to three possible appearances (Table VII). This table would seem to emphasize the frequency of multiple hypertrophic changes among old employees, and would apparently point toward (a) heavy labor as a cause of the condition and (b) the occurrence of multiple hypertrophic lesions as a cause for the rejection of an individual for heavy labor.

The general group with backache was made up of men and women from nearly all walks of life, but none of the women were stevedores. Table VIII brings out several facts concerning these women: (a) Hypertrophic changes occurred about 50 per cent. more frequently among women than among men; (b) multiple lesions were more frequent in women; and (c) the three areas in which the women showed a more marked predominance of hypertrophic changes than the men were the thoracic, sacro-iliac, and iliolumbar regions. These three areas are the ones most subject to the ever-increasing strains of childbearing. The thoracic area takes the strain throughout the period of gestation, while the pelvic ligaments are more subject to the periodic relaxations of the pelvis and the occasional bursting strains of childbirth. The greater obliquity of the female pelvis may also play a part in this predominance.

TABLE VIII

LOCATIONS OF LESIONS

	470 Males (*Per Cent.*)	90 Females (*Per Cent.*)
Longitudinal ligaments	42.5	44.5
Cervical	1.5	2.2
Thoracic	3.5	8.9
Lumbar	37.5	33.3
Iliolumbar region	9.1	15.5
Sacro-iliac region	24.7	49.8

The reason for this study is that improvement in the treatment of dysfunction in other fields of medicine has followed in the wake of a quantitative definition of normal function.

By the application of special resources, herein described, human locomotion has been recorded. The normal characteristics have been measured, and the stance phase has been expressed in a single curve, as related to time and pressure.

Likewise, it has been shown that any significant dysfunction of human locomotion is characterized by a gross departure from the normal curve of the stance phase.

The application of these resources to clinical problems provides for the evaluation of therapeutic results on the basis of measurement instead of memory.

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DISCUSSION

Dr. Verne Inman, San Francisco, California: The present studies of Dr. Schwartz have resulted in an improvement over the previous methods by indicating the pressure transmitted through the various portions of the foot, as well as the time interval of contact. The piezometric discs are ingenious and, if they are as readily calibrated as indicated in the paper, the discs will certainly have a wider application. The lack of an adequate mechanism for the measurement of pressure has been a stumbling block to engineers, as well as to investigators in the biological field. I regret that Dr. Schwartz did not give more minute details of construction in his publication, but sincerely hope that he will make them available to other workers.

The present study shows the progressive transference of weight from the heel through the fore part of the foot in normal and pathological gaits. The *time* of transference of pressure through the selected parts of the foot is nicely shown. However, I should like to ask Dr. Schwartz if it is not true that only the pressures transmitted through the areas covered by the discs are recorded and not the total pressures of the foot, since other areas than those beneath the discs may be in contact with the floor. Furthermore, the pressure discs record only vertical forces, and it would be exceedingly interesting to know if sheers or torques are present as weight is borne upon the foot. To obtain these latter data, it seems to me, the use of a force plate would be required.

As Dr. Schwartz himself indicates, the study of human locomotion is complex, and I believe the full value of his work will not be appreciated until it is correlated with the motion of the other segments of the lower extremity. It is hoped that such investigations will soon be undertaken.

Dr. Robert W. Johnson, Baltimore, Maryland: In these few minutes, Dr. Schwartz has given the distillate of many long and tedious hours of experimentation and observation. I recall well a visit to his laboratory a number of years ago, where flashing lights revealed the earliest patterns of the tread mechanism of locomotion. Following through his series of articles, one sees the va[illegible] ingeniously met; and it would seem that now he has definitely established the time seq[illegible]

AN IMPROVED SKIN-TRACTION TECHNIQUE FOR THE FINGERS

BY LIEUTENANT COLONEL HARTWIN A. SCHULZE
Medical Corps, United States Army

The conservative methods of treating oblique fractures of the metacarpals and the proximal phalanges of the fingers ordinarily require prolonged traction. To meet this need the fingernail method and the soft-tissue transfixion method are usually inadequate. The skin-traction methods which employ various types of adhesive tape or glue are also unsatisfactory, because of early slipping. For these reasons skeletal traction, employing Kirschner wires or tongs, is ordinarily considered the method of choice. The application of skeletal traction, however, has the disadvantages of requiring an expert operator, a precise technique, and special equipment. It is accordingly time-consuming.

Since the skin of the fingers is tough and relatively immobile, skin traction at this site

FIG. 1
Application of bias muslin binder over crinoline gauze.

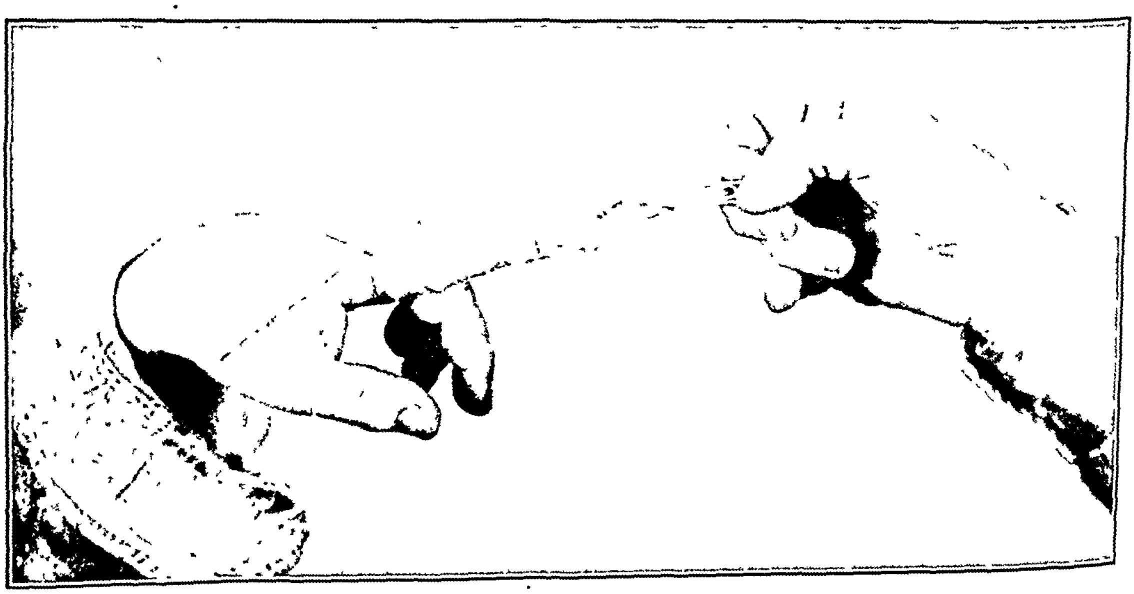

FIG. 2
The completed device, ready for the application of traction.

PRE-EMPLOYMENT EXAMINATIONS OF THE BACK *

BY STEELE F. STEWART, M.D., HONOLULU, TERRITORY OF HAWAII

This presentation is the account of an attempt to prevent and to eliminate backache among men engaged in a heavy industry,—stevedoring. The types of backache will be reviewed briefly, and perhaps reclassified.

1. Referred backaches, resulting from abnormalities of the prostate, gall bladder, or other organ, do not come within the scope of this study.

2. Acute traumatic backache as the result of falls or direct blows may come to any man and, since they cannot be anticipated, do not fall within the field of preventive medicine or of this paper.

3. Acute atraumatic backaches are of two general types:

A. The first type may arise from several diverse but related causes,—such as fatigue, exposure, or salt deficiency.

Fatigue is produced (1) when a novice does unaccustomed tasks for a prolonged period (as Holman Day observed, "No one knows how many backaches are in an old stun wall."); (2) by uneconomical posture; (3) by sleeping as if suspended by one's head and heels in a sagging bed; or (4) by doing monotonous repetitive acts. It is this last cause which enters into most backaches in stevedores, which arise from handling cargo. For example, in working with sugar, each man picks up, carries, and stacks a hundred-pound sack of sugar every seventy-nine seconds, eight hours a day. With pineapples, each man handles a fifty-five-pound case of pineapples every forty-five seconds throughout the day. Stevedoring is therefore a very active occupation, and there is little opportunity for postural or static difficulties to develop. Hence postural peculiarities are not considered in this group.

Exposure is the second major cause of this type of backache. In the tropics, it may be the result of working with "icehouse" cargo or sitting in sweat-soaked clothing under the chilling effect of the balmy trade wind. This causal relationship was noted by Pasquin a century and a half ago, when he wrote: "He's lumbagoed [by the north or east wind] the rest of his days".

Salt deficiency is not at all uncommon in the tropics.

These causes may be present singly or jointly. In backaches from these causes, the muscles feel as though they had jelled; motions are slow and painful; the affected metameres are cooler than the adjacent ones; and the person tends to become limber with diverse activity. To relieve these backaches, the Polynesians have their children walk on their backs; personal experience has shown this treatment to be dramatically effective.

The problems presented by these backaches are in part medical, but for the most part they arise from the working habits of the men and the conditions imposed by the types of cargo and the places in which they work.

B. The second clinical type of acute atraumatic backache is usually attributed to a "sprain", arising from lifting anything heavier than a cigarette paper. The motions producing the backache are usually flexion and twisting. The condition is acutely painful and very disabling; hence it is called acute. In reality, it is usually chronic, because it is frequently episodic. It is to this group that the present study has been especially directed.

The author first encountered this problem in 1942, when he went to Honolulu and became associated with the Medical Group, an established firm which had been caring for about 850 stevedores for the Castle and Cooke Terminals, Limited. The first problem presented was backache in stevedores.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

When the materials are removed, it will be seen that the skin has a grilled appearance, with the depressions corresponding to the threads of the gauze (Fig. 3). This factor, rather than the adhesive properties of the lacquer, undoubtedly accounts for the greater part of the non-slipping properties of the device. This same principle has a diversity of applications in various fields of engineering.

When this method is used, the only caution necessary is to avoid constriction. If the binder is applied too tightly, it will be apparent in the exposed finger tip within a few minutes. If evidence of constriction is not apparent at that time, it is unlikely to develop. The patient should, however, be instructed to make frequent observations during the first day. The hand should, of course, be carried in a sling.

The only maintenance necessary is to see that the binder does not get too loose. If this happens, a second binder can be applied directly over the first.

This method of traction has the following advantages: It does not slip even when continued over a prolonged period; it can be applied in a few minutes; a technician can readily apply it; and it avoids the risks inherent in skeletal traction. The only disadvantage is that it cannot be used for fractures distal to the proximal phalanx or in the presence of certain concomitant finger injuries.

The author has used this method for many fractures of the metacarpals and proximal phalanges of the fingers without experiencing any failures.

INFANTILE CORTICAL HYPEROSTOSIS

BY DOUGLAS D. DICKSON, M.D., CLARENCE A. LUCKEY, M.D., AND NOBLE H. LOGAN, M.D., OAKLAND, CALIFORNIA

Infantile cortical hyperostosis is the descriptive title used by Caffey and Silverman[1] in reporting four cases of a disturbance involving primarily the skeletal system of infants. Their cases were characterized by the sudden onset, within the first three months of life, of tender swelling, the location depending upon the bone or bones affected. Involvement was noted in the tibiae, femora, ribs, humeri, radii, ulnae, clavicles, mandible, and scapula; but not all of these bones were involved in any individual case. There was a striking absence of general systemic manifestations. An elevation of temperature was noted in two of four cases at the onset, and was present later in a third case. Roentgenographic findings revealed cortical thickening and lamination in many instances, with normal-appearing spongiosa, metaphyses, epiphyseal plates, and ossification centers in the epiphyses. Other laboratory studies revealed no significant findings. After many weeks the swelling subsided and no sequelae were noted.

CASE REPORT

S. W. was a full-term female infant, delivered without difficulty or complications on July 12, 1945. At the age of one week, orange juice and cod-liver oil were included in the formula. Nutritional requirements have been met up to the present time. At the age of two months, the mother first noted swelling over the right scapular region. Examination at that time revealed a hard mass over the region of the

TABLE II

COMPARISON OF BACKACHES IN GROUPS WITH AND WITHOUT PRE-EMPLOYMENT EXAMINATIONS *

	No. of Men	No. of Backaches	Treatments		Days Lost	
			Total	Average	Total	Average
Stevedores not examined (at least 612)						
First backache	42	42	276	6.6	110	2.6
Subsequent backaches	19	26	86	4.5	47	2.5
Stevedores examined (at least 238)						
First backache	14	14	42	3.0	28	2.0
Subsequent backaches	3	3	7	2.3	3	1.0
	78	85	411	5.3	188	2.4

* Figures supplied by Castle and Cooke Terminals, Ltd.

point, it is mostly machine work. In the hold, every article is moved into its proper place entirely by human strength. The machine operators, hatch tenders, and winch drivers need clear heads; those in the hold, strong backs. It is in the latter group that careful back examinations are required.

Cargo is classified into four main groups: (1) general, (2) special, (3) "icehouse", and (4) bulk cargo. *General cargo* is made up of objects of assorted sizes, shapes, and weights, such as household goods. *Special, or repetitive, cargo* consists of objects identical in shape and weight, such as cases of pineapples or sacks of sugar; in handling this cargo, the motions of the stevedores are necessarily repetitious. Work on both of these types of cargo is usually done in hot, stuffy holds. In contrast to these is *"icehouse" cargo,* which is usually of the special type, but is handled at temperatures as low as 10 degrees Fahrenheit. Finally there is *bulk cargo,* such as molasses, oil, grains, and ore. Bulk cargo was not handled by the stevedores discussed here.

With these facts in mind, a scale of employability for stevedores was set up:

Group A: Patients with *good* backs, who exhibited no abnormality by roentgenograms;

Group B: Patients with *fair* backs, who exhibited spina bifida occulta of a single segment, slight asymmetry of the facets, limbus bodies, very early hypertrophic changes, well-reduced healed fractures of the centrum, and old fractures (healed or unhealed) of the transverse processes;

Group C: Those with *poor* backs, who presented marked asymmetry of the facets, sacralized transverse processes, spina bifida involving more than one segment, hemivertebrae, spondylolysis, spondylolisthesis, thin intervertebral discs, Schmorl's nodules, marked hypertrophic changes, and sclerosis of the aorta.

Men in the first two groups were employed; those in Group C were considered not employable.

These standards resulted in the rejection of 51 per cent. of the applicants. However, the man-power shortage was so acute that it was considered necessary to employ some of the better of the poor risks. A fourth group was therefore designated as "questionable risks", in which were included applicants with asymmetry of the facets, severe spina bifida occulta, and moderate hypertrophic changes. The members of this group were then questioned by the Personnel Manager as to a history of backache. If the history was positive, the man was rejected; if negative, he was employed. This method lowered the rejection rate to 30.5 per cent.

RESULTS

The employer is interested in two things: a reduction of the incidence of industrial backache, and a reduced period of disability. 1941 and 1942 were the last two years in

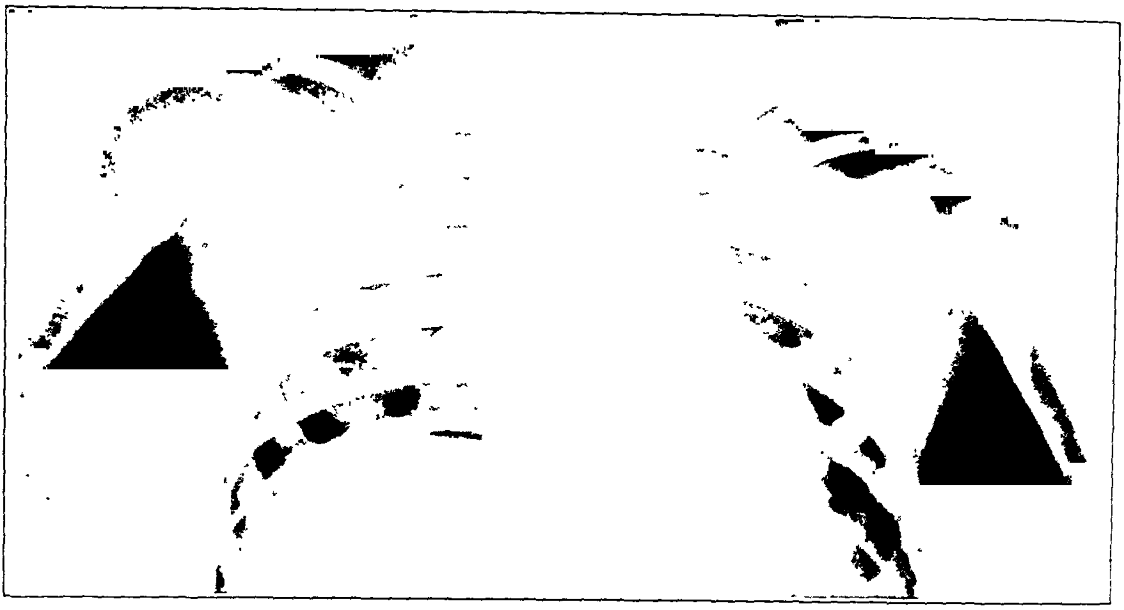

FIG. 4

Showing restoration of normal bone pattern in both clavicle and scapula.

Then gradual regression of the mass began. Roentgenograms taken on November 11, 1945, showed that the bony proliferation in the right scapular region had subsided considerably. On April 5, 1946, the roentgenograms showed only slight residual thickening of the right scapula. Final roentgenograms on April 26, 1946, revealed a normal bone pattern throughout the entire skeletal system (Fig. 4). The Kahn and Kline tests and the Wassermann reaction were negative.

During the hospital stay, there was elevation of temperature to 100.6 degrees by rectum on one occasion; usually the temperature was not over 99.5 degrees by rectum. There was adequate vitamin intake previous to, and during, the hospital stay.

TABLE I

HEMATOLOGICAL FINDINGS

Date	ANALYSIS			DIFFERENTIAL COUNT			
	R.B.C.	Hemoglobin	W.B.C.	Neutrophils	Lymphocytes	Monocytes	Eosinophils
Sept. 29	3,040,000	8.2 grams	17,450	71	21	6	2
Oct. 12	3,140,000	7.9 grams	14,550	37	57	6	
Oct. 18*	6,550,000	23.4 grams					

* Following transfusion.

The etiology is obscure. Whether or not this is a response to infection, cannot be settled easily. The biopsy does not suggest that osteomyelitis is the cause; however, infants may respond differently than adults in the presence of a hematogenous osseous inflammatory lesion. It has been noted frequently that osteomyelitis in the infant is benign and produces no sequestra.

1. CAFFEY, J., AND SILVERMAN, W. A.: Infantile Cortical Hyperostoses; Preliminary Report on a New Syndrome. Am. J. Roentgenol., 54: 1–16, 1945.

TABLE IV

FACTORS CAUSING BACKACHE

	Group Examined Before Employment (*Per Cent.*)	Private Patients (*Per Cent.*)	Old Employees (*Per Cent.*)
Spondylolisthesis	3.8	4.6	2.3
Sacralized transverse process	5.1	8.7	3.8
Thin disc	10.2	25.7	9.9

TABLE V

CONDITIONS WHICH MIGHT PREDISPOSE TO BACKACHE

	Group Examined Before Employment (*Per Cent.*)	Private Patients (*Per Cent.*)	Old Employees (*Per Cent.*)
Asymmetrical facets	26.6	35.0	34.3
Schmorl's nodules	0.95	1.6	2.3
Hypertrophic changes	54.5	61.8	71.0

Neckache occurred in 1.4 per cent. of the patients, thoracic backache in 2.5 per cent., and low backache in 96 per cent. Therefore, a roentgenographic study of the lower part of the back will disclose the potential causes of backache in 96 per cent. of those examined.

2. To determine the relative significance of congenital and acquired defects in the production of backache, each of the three groups—the private patients, the old employees, and the pre-employment group—may be divided into four subclasses, which may then be compared (Table III). From these figures it is apparent that (a) normal backs are fewer in individuals complaining of backache than in an unselected group; (b) employment at heavy labor apparently tends to eliminate individuals with certain congenital defects or causes secondary defects to develop; and (c) acquired defects are of distinctly greater significance in the backache groups than are congenital anomalies.

3. In considering the congenital anomalies which tend to cause an individual to be excluded from heavy labor, it has been assumed that the pre-employment group of 1049 men represent a run-of-the-mill cross section of men engaged in hard labor; that the 560 patients with backache represent a fair sample of individuals with backache; and that the 131 old employees complaining of backache, who were not examined before being employed, would show the eliminative effects of stevedoring on the incidence of back defects. Table IV would seem to point toward three defects—spondylolisthesis, sacralized transverse processes, and thin discs—as the defects most likely to caüse disabling backaches among persons performing heavy labor.

4. An effort was made to determine whether there were any defects which, if increased in both groups with backache, would tend to point toward their being predisposing factors to backache (Table V). Heavy labor might either cause the greater incidence of Schmorl's nodules and of hypertrophic changes among the old employees, or it might cause more

TABLE VI

FREQUENCY OF OCCURRENCE

	Group Examined Before Employment (*Per Cent.*)	Private Patients (*Per Cent.*)	Old Employees (*Per Cent.*)
Spondylolysis	4.6	4.1	5.3
Spina bifida occulta	19.0	16.7	27.2
Wedge vertebrae	1.4	1.0	6.9

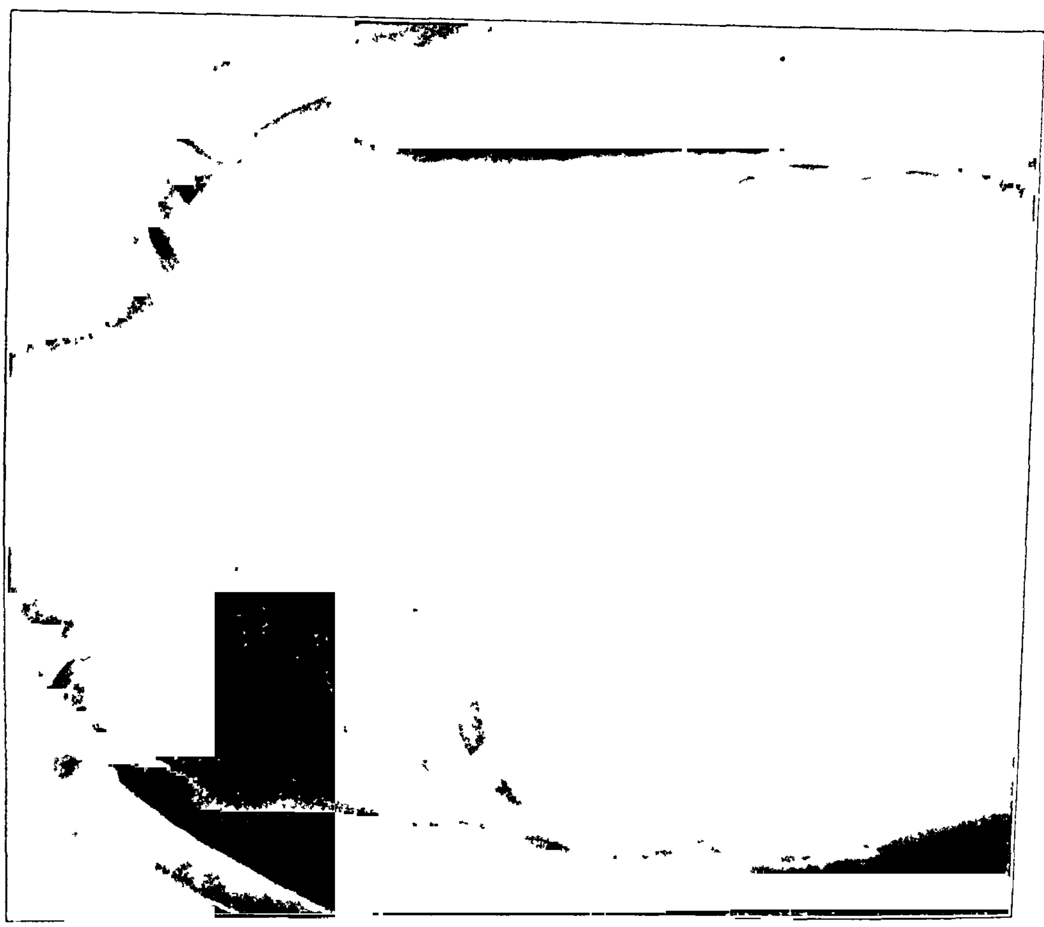

FIG. 1
Shows osteomyelitic lesions of almost all ribs and of right scapula.

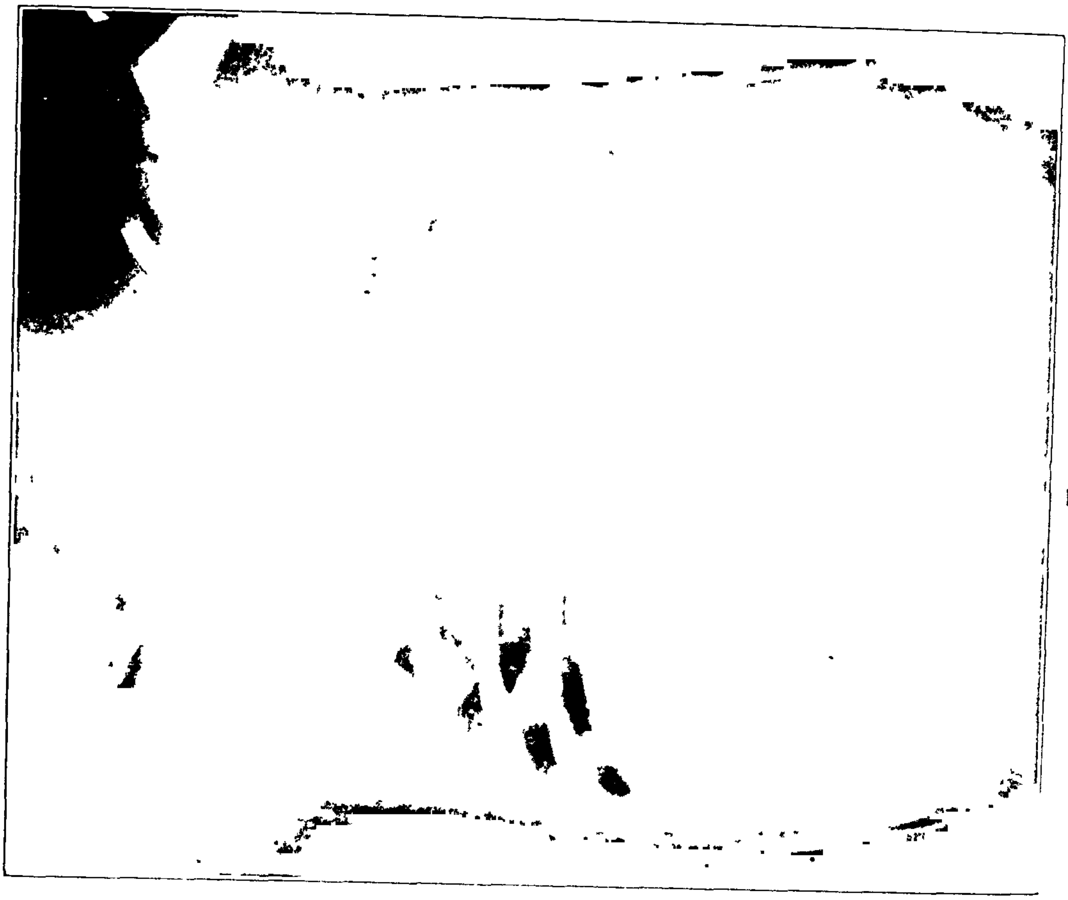

FIG. 2
Roentgenogram of chest, taken on October 20, 1945

From these facts we may conclude (a) that the incidence of backache in the sacro-iliac or iliolumbar region is nearly twice as great in women as in men; and (b) that a different set of criteria would be required for prospective women employees.

7. The rarer vertebral anomalies, such as a hemivertebra or a limbus body, have appeared so seldom that it is impossible to draw statistical conclusions. However, judging from limited experience, the author would rate an applicant with a hemivertebra as a poor risk, because this is an asymmetrical development which throws unusual strains on the muscles and ligaments; and, in the older cases seen, the hypertrophic changes have been marked. A limbus body, on the other hand, is a symmetrical development that dates back to amphibian days, where it appeared as the intercentrum in Seymouria. It causes no unusual strains, and hence an applicant with a limbus body would be rated as a good risk. A candidate having a well-reduced and healed fracture of the centrum would be rated as fair, while one with a poorly reduced fracture would receive a poor rating.

8. When rated on the same basis as the pre-employment group, 33 per cent. of the old employees were rated as employable and 67 per cent. as unemployable. Thus the figures for the two groups are nearly reversed. This may mean either that the work is productive of disability or that many persons who were bad risks were employed prior to the institution of the pre-employment roentgenographic examinations of the back. The fact that the so-called old employees averaged about five years younger than the pre-employment group would certainly suggest the latter explanation.

It would appear that the next stage of this work should be the reduction of the type of backache associated with handling repetitive cargo. The following program should be instituted:

(a) Stevedores should alternate the side presented to the stowed cargo every fifteen or thirty minutes, so as to distribute the working load evenly on the two sides of the back.

(b) The stevedores working in hot holds should be supplied with adequate water, and should be compelled to take enteric-coated salt tablets in sufficient amounts to balance the salt loss.

(c) The stevedores should be instructed in the value of resting in dry clothing during the noon hour.

(d) Stevedores working with "icehouse" cargo should have warm drinks or soups available, and should protect their loins with a warm binder. As long ago as 1620, Venner observed that "some soft woolen cloth will preserve from lumbaginous pains".

A system that finds 30 per cent. of thirty-year-old males unfit for heavy labor is freighted with heavy social implications. Some of the men were illiterate and some stupid, but generally they were of average intelligence. Some of the physical defects were beyond remedy, but some of the men could be converted from social liabilities to social assets. The remediable conditions could all have been recognized before the individuals left school; an appraisal of our adolescents would give an opportunity to guide them away from channels for which they are physically unfit.

DISCUSSION

Dr. Philip Lewin, Chicago, Illinois: I would like to ask two questions: The first is the labor-union aspect, because in Chicago, twenty years or more ago, a group of men (industrial surgeons and roentgenologists) attempted to do this, but the unions prohibited it. Second, what about bilateral sacralization of the fifth lumbar vertebra as compared to unilateral sacralization?

Dr. Steele Stewart (closing): In answer to Dr. Lewin, not only have the men cooperated, but the labor unions have cooperated. This is probably due in a small way to the manner in which the problem was approached and the way it was handled. When a man applies for a job as a stevedore, he is sent to the Medical Group, examined by one man, and a permanent record is made. He is then sent to the x-ray room and three roentgenograms are taken,—one as the back lies on the table, one with the back flat, and a lateral view. The report is written up and sent to the employer, stating the exact condition found in

(*Continued on page 236*)

Fig. 4

Fig 5

Roentgenograms taken on March 21, 1916

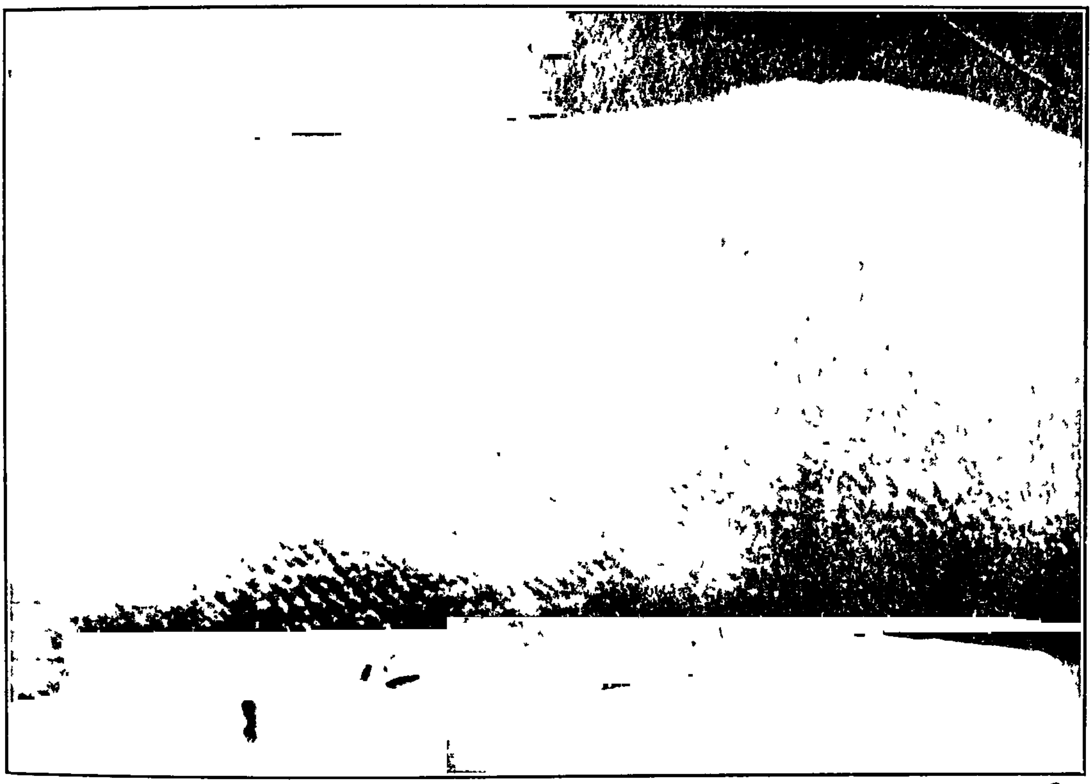

FIG 3

Grilled appearance of the skin after removal of the gauze. (× 3)

would seem to offer some special advantages, if only slipping could be avoided. Slipping is usually due to a low viscosity of the adhesive substance, and a further reduction of its viscosity by the absorption of the secretions of the skin.

The method described here avoids these difficulties by employing a non-viscid adhesive substance and a bonding technique which depends upon precise coaptation of two irregular, apposing surfaces. Such coaptation is produced by placing a coarse-meshed gauze in contact with the skin, under slight pressure.

The following materials are required:

1. A lacquer with a cellulose base. Most fingernail lacquers are of this type, and there are many lacquers of this kind on the market for general use.

2. A strip of crinoline gauze, having twenty to thirty threads to the inch. This is the starched gauze used in making plaster bandages.*

3. A roll of bias muslin, one-half inch wide. This can be sliced with a knife from an ordinary roll of bias muslin bandage.

The procedure is as follows: The finger is given a liberal coating of lacquer. A strip of the gauze, about one and one-half inches wide and about ten inches long, is applied to the dorsum and the ventrum of the finger, with the loop extending about two inches beyond the tip of the finger. The gauze is bound snugly in place with a strip of half-inch bias muslin, applied in a simple spiral fashion. The muslin binder extends from the base of the finger to the base of the nail and back to the base of the finger (Fig. 1). The end is secured with a bit of adhesive tape. The muslin is kept in place with a narrow strip of adhesive tape, applied as a wide-open spiral. The protruding gauze loop is smeared with lacquer and rolled into a cord. To prevent pressure on the finger tip, a cork disc, cut from a bottle stopper, is used as a spreader. It is placed inside the loop, and held in place with an encircling strip of adhesive tape. Traction can be applied immediately (Fig. 2).

* Surgical gauze of similar mesh, having a hard texture and large threads, may be used, but it is more difficult to handle. Bookbinders' gauze, which is stiffened with glue instead of with starch, is also satisfactory.

Since many of the 150 or more types of Salmonella organisms may cause disease in man, it is not surprising to find various types also as causative agents of osteomyelitis. Much of the older literature on Salmonella infections is of limited value today, in so far as type diagnosis is concerned. For example, in the light of present-day knowledge of the antigenic structure of Salmonella organisms, the paratyphoid Erzinjan bacillus isolated by Ssokoloff may have been *Salmonella enteritidis* (variety from Moscow).

In the present case, the diagnosis of the osteomyelitic lesions in the various bones was established both by clinical and roentgenographic examinations. That the osteomyelitis was due to an actual infection by the Salmonella organism was proved by microscopic and bacteriological examination of the material removed at operation from the involved right ilium. Microscopically, gram-negative bacilli were seen; the culture produced a pure growth of *Salmonella typhimurium*. The biopsy specimen was obtained at a time when the blood culture had become sterile. Consequently, the presence of these micro-organisms was not due to contaminating blood. It seems fair to assume that the osteomyelitic lesions in the other bones were due likewise to actual infection.

Complete recovery took place in the present case. It is impossible to appraise the role played by the sulfonamides and penicillin in the favorable outcome.

NOTE: The author wishes to thank Erwin Neter, M.D., and G. Newton Scatchard, M.D., for the bacteriological and roentgenographic data.

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SALMONELLA INFECTION INVOLVING THE KNEE JOINT

REPORT OF A CASE*

BY THEODORE H. VINKE, M.D., AND HAROLD F. DOWNING, M.D., CINCINNATI, OHIO

A six-months-old white infant was admitted to the Children's Hospital, Cincinnati, on April 7 1945. A history was obtained that, on April 1, the child had been cross and irritable and his right knee gradually became stiff. The child held the knee in a flexed position and refused to extend it. These symptoms persisted until the time of the first examination.

One month prior to the onset of symptoms, the child had diarrhoea, lasting two weeks. He had had no other illnesses, and the family history was not contributory.

On physical examination, the child appeared well developed and well nourished. He did not appear to be acutely ill, although he was irritable. The skin was dry and no eruption was present. The eyes ears, nose, and throat were normal. There were no palpable lymph nodes. The lungs were normal and clear to percussion and auscultation. The heart was not enlarged; the rhythm was regular; and the sounds were of good quality. The abdomen had a convex contour. There was no tenderness or rigidity.

* Read before the Clinical Orthopaedic Society, Cincinnati, Ohio, October 1945.

right scapula with invasion into the right axilla. There was some duskiness of the skin over this area. The first roentgenograms (Fig. 1) were taken on September 18, 1945. They revealed moderate bony overgrowth of the wing of the scapula, together with thickening of the surrounding soft tissue. Films taken on September 28, 1945, showed an increased reaction in the scapula. Some cortical thickening of the mandible was also demonstrated at that time. Subsequent roentgenograms taken on October 8 and October 15, 1945, showed considerable extension of the process in the scapula and also involvement of the clavicle on the same side (Fig. 2). A biopsy was done on September 28, 1945. There was considerable oedema of the muscles overlying the mass. Microscopic examination revealed invasion of the muscle with inflammatory cells (Figs. 3-A and 3-B).

Fig. 1

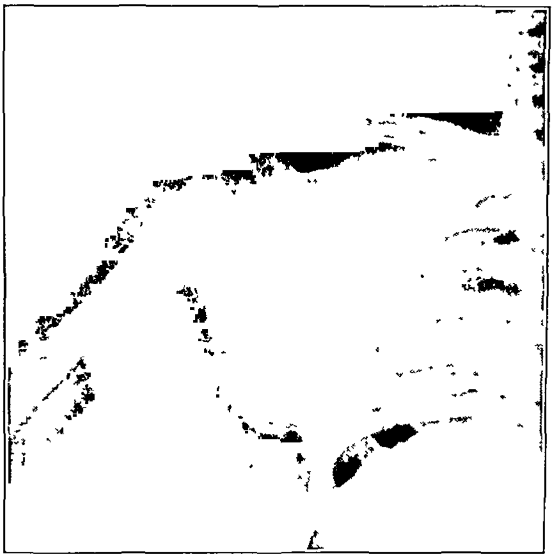

Fig. 2

Fig. 1: Demonstrating marked bony thickening of the scapula.
Fig. 2: Illustrating further thickening of scapula, and bony proliferation involving the clavicle.

Fig. 3-A

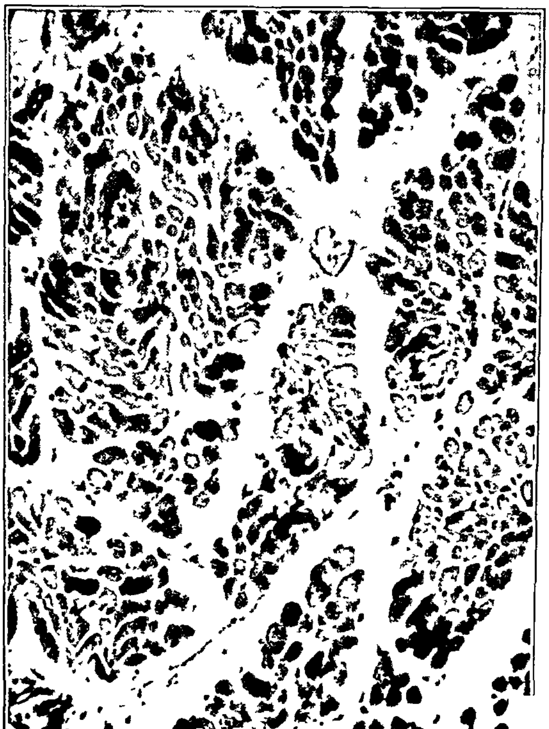

Fig. 3-B

Invasion of the infraspinatus muscle with inflammatory cells.

UNUNITED EPIPHYSIS OF THE ISCHIUM

Report of a Case

BY HARRY WINKLER, M.D., AND IRA H. RAPP, M.D., CHARLOTTE, NORTH CAROLINA

During recent years, interest has been directed to a rather infrequent lesion of the tuberosity of the ischium, designated variously as "avulsion fracture of the ischial tuberosity", "isolated fracture of the ischium", "hamstring avulsion", "epiphysitis of the tuberosity of the ischium". Fractures of the ischium are usually associated with multiple fractures of the pelvis, and are commonly the result of direct violence. Heretofore, fracture of the ischium, due to indirect violence, was thought to be exceedingly rare. Cotton failed to report a single case, although he recognized the possibility of its occurrence. Key and Conwell state: "Fracture of the tuberosity of the ischium is a very rare injury". Watson-Jones records the fracture as "hamstring avulsion". The first reported case in the American literature was that of Berry's in 1912, and since that time other authors have reported its occurrence[1,3,7,8,9].

The mechanism of fracture, or, more properly, epiphyseal avulsion, is a violent force, transmitted indirectly by contraction of the hamstring muscles to the secondary epiphysis of the tuberosity of the ischium. The ischium is ossified through two centers, one primary and one secondary. The secondary center for the tuberosity does not appear until puberty, and is not completely united to the body until the age of twenty-five[5]. It is, therefore, a fracture of early life. The displacement of the fragment is determined by a resultant force, which in turn is the product of multiple component forces: the hamstrings and adductor magnus pulling downward, outward, and forward; the quadratus femoris and gemellus inferior pulling upward, outward, and forward; and the sacrotuberous ligament, the direct antagonistic force, preventing a thrust downward, outward, and forward.

The history is highly suggestive of the diagnosis; the injury is usually sustained while the person is running and when the hamstrings are in the active phase of contraction, although in Milch's case the patient was doing the "split" in a fancy dance. There is sudden and severe pain in the involved buttock, and walking becomes painful or impossible. The patient subsequently improves on conservative therapy, although he may be subject to minor exacerbations of pain with strenuous exercise or prolonged weight-bearing. The course of events then may be toward complete symptomatic improvement; or the detached epiphysis may become enlarged, necessitating operative removal. With the exception of the case reported by Berry, surgical removal of the lesion has not been undertaken.

This case is presented because of the persistence and progression of symptoms which necessitated the removal of the fragment, and afforded an opportunity for study of the tissue histologically.

P. S., a man, aged thirty-nine, stated that, at the age of fourteen, he had been participating in a broad jump. While running and preparing for the leap, he felt something "snap" and immediately he experienced severe pain in his left buttock, which radiated along the posterior aspect of the thigh. He fell and had to be carried from the field of play. The family physician advised bed rest, and after several days of rest he returned to school. Later he was able to participate actively in baseball, but experienced minor exacerbations of pain in the buttock and weakness of the left leg.

In January 1946, because of persistent and increasing pain, especially when sitting, he sought medical aid. On clinical examination, the patient was observed to be a generally well-developed and well-nourished white male. No abnormality of gait was noted, and his posture was not remarkable. The lengths of the legs were equal, and the muscle power in both lower extremities was rated from good to normal. There was no change in reflexes of the lower extremities. Local examination disclosed a firm, smooth, non-movable mass posteriorly, in the region of the left buttock; otherwise the general physical examination was essentially negative. A roentgenogram taken at that time revealed a large detached

OSTEOMYELITIS CAUSED BY *SALMONELLA TYPHIMURIUM*

BY RUTH F. KRAUSS, M.D., BUFFALO, NEW YORK

From the Children's Hospital and the University of Buffalo School of Medicine, Buffalo

It is generally recognized that osteomyelitis in man may be caused by a variety of micro-organisms. Most commonly encountered are the Staphylococcus and beta-hemolytic Streptococcus, and less often the pneumococcus, influenza bacillus, typhoid bacillus, and others. That Salmonella organisms only rarely cause an infection of bones and joints is evidenced by the fact that, even though the first of such cases was described as early as 1896, a review of the literature in 1940 by the Uruguayan investigators, Guerra, Peluffo, and Aleppo, disclosed but fifteen authentic cases. *Salmonella suipestifer* (*Salmonella cholcraesuis*) was the causative agent in twelve of the fifteen cases reviewed by Guerra and his associates. In the remaining three cases, *Salmonella typhimurium* was the incitant in two instances and *Salmonella enteritidis* in one. Other Salmonella types have been recovered from osteomyelitic lesions,—for example, *Salmonella panama*[1] and *Salmonella schottmülleri*[2]. A search of the literature failed to disclose a report of osteomyelitis due to *Salmonella typhimurium* in which a large number of bones were involved. The pertinent clinical, bacteriological, immunological, and roentgenographic aspects of such a case are, therefore, presented here.

CASE REPORT

F. J., a white boy, two and one-half years old, was admitted to the Children's Hospital on September 2, 1945. The family history and the past history were non-contributory. The present illness began on September 1, with fever and listlessness. On admission to the Hospital, the boy's temperature was 106.4 degrees, the pulse rate was 150, and the respiratory rate was 35 per minute. The patient was well developed and well nourished, but appeared pale, listless, and acutely ill. His neck was stiff. Examination of the chest revealed diminished resonance and tubular respiration on the left side. No other significant changes were noted.

Clinical Course

During the first fortnight, the patient's general condition remained serious. The temperature fluctuated between 102 and 105 degrees during the first week, and then ranged from 99 to 105 degrees during the following week. Roentgenographic examination of the chest showed small amounts of fluid in both pleural cavities. On September 15, aspiration yielded eighty-five cubic centimeters of straw-colored fluid from the left pleural cavity; this fluid proved to be sterile on culture. During the next two weeks the general condition of the patient improved, and the temperature reached lower levels (99 to 103 degrees). Early in October, about one month after admission, tenderness over the ribs and the right scapula was noted. Roentgenographic examination disclosed for the first time widespread osteomyelitic lesions of almost all the ribs and of the right scapula (Fig. 1). The wings of the ilia also were involved; but all other bones appeared to be normal. On October 20, new osteomyelitic lesions were discovered roentgenographically in the neck of the left femur and in the portion of the right ilium adjacent to the acetabulum. Figure 2 is a reproduction of the roentgenogram of the chest, taken on that day. The patient's general condition showed continued improvement, and the temperature became normal two months after admission to the Hospital.

On November 6, roentgenographic studies showed marked improvement of the lesions of the ribs. right scapula, wings of the ilia, and neck of the left femur. Figure 3 is a reproduction of the roentgenogram taken then, showing involvement of both ilia, the left hip, and the right acetabulum. Medial displacement of the right ischium and pubis indicated involvement of the cartilage. On November 21, when the patient was re-examined, the ribs were almost normal in appearance; however, there was no change in the dislocation of the ischium and pubis.

The child was examined again on March 21, 1946, approximately six and one-half months after the onset of illness, and he appeared clinically well. The roentgenographic appearance of the ribs and right scapula was normal (Fig. 4) and only a slight residual deformity was present in the wings of the ilia and in the right acetabulum (Fig. 5).

crescent-shaped fragment in the region of the left ischial tuberosity. On February 2 the mass was excised by the senior author. With the patient in the lithotomy position, a longitudinal incision was made from the superior margin of the pubis on the left, extending in a downward and parallel direction to the inferior pubic ramus. On deeper dissection, a firm mass was encountered, which was roughly ovoid in shape and approximately three inches in length. The line of cleavage between the normal bone of the ischium and that of the tumor was identified, and the mass was removed by dissection in this plane. This tissue, with shavings from the line of attachment, was sent for pathological examination.

The pathological report revealed an ovoid mass, measuring 7 by 4.5 by 4 centimeters. Histologically, the tissue resembled normal osseous matter with normal marrow elements, the exterior being partially lined by hyaline cartilage and dense tendinous connective tissue. Microscopic sections of the shavings from the line of attachment of the mass showed resting hyaline cartilage, with a paucity of nuclei and with areas of transition into dense connective tissue of the tendinous type.

The patient made an uneventful recovery, and six months later is asymptomatic with no weakness of the left leg; he can now sit comfortably for any length of time.

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Steele F. Stewart (*Continued from page 221*)

the back. The man is brought in and the statement is read to him by a member of the Personnel Department. The staff of that Department have been instructed as well as they can be that, when a serious condition appears in the report, they should try to explain it to the man so that he will understand it. If he cannot understand it, he has the privilege of coming to see me without cost; I will go over the roentgenograms and explain the condition to him. In other words, we have a very high degree of personal relationship with the individuals. I think the closer we can come to personal relationships in our labor dealings, the less trouble we are going to have with labor unions in this sort of thing.

Regarding bilateral sacralization, I do not believe this is as dangerous a risk as unilateral sacralization. We must remember that, in bilateral sacralization of the transverse process, we are likely to have a thin disc, and that a thin disc is anatomical and physiological,—not an abnormal disc. That type would not fall into the group we have mentioned.

FIG. 3
On November 6, there was involvement of both ilia, the left hip, and the right acetabulum.

Therapy

The patient was given one grain of sulfadiazine per pound of body weight (thirty grains) by mouth each twenty-four hours during the first five days in the Hospital. This treatment was resumed on the seventh hospital day, and continued for one week. The resulting blood levels ranged between three and six milligrams per 100 cubic centimeters. From September 17 to December 10, the dosage of sulfadiazine was doubled (sixty grains in twenty-four hours); this resulted in concentrations of the drug in the blood ranging from seven to twelve milligrams per 100 cubic centimeters.

During the first eleven days in the Hospital, the patient was also given from 120,000 to 150,000 units of sodium penicillin intramuscularly each day, in eight divided doses, although it was appreciated that this drug is largely ineffective against Salmonella organisms. During the first ten critical days, the child was given oxygen. Eight blood transfusions, varying in amounts from 80 to 150 cubic centimeters, were given during the first two weeks.

Laboratory Findings

Blood Cultures: A blood culture, taken on September 2, contained gram-negative bacilli with the morphological, cultural, and antigenic characteristics of *Salmonella typhimurium*. The number of organisms per cubic centimeter of blood was too large to be determined. A blood specimen, taken on September 5, was also positive for *Salmonella typhimurium*. On September 14, fifty-two colonies of *Salmonella typhimurium* per cubic centimeter of blood were present. On September 19, the number of Salmonella organisms was greatly reduced, since they were recovered only from the broth culture and not from the blood agar. Subsequent blood cultures, taken on September 25 and October 1, 1945, remained sterile. These data, therefore, indicate that the patient had been suffering from *Salmonella typhimurium* bacteriaemia over a period of at least two and one-half weeks.

Biopsy Culture: Culture of the material obtained by biopsy from the ilium showed the presence of *Salmonella typhimurium*. The histological examination of the biopsy specimen by K. L. Terplan, M.D., revealed the presence of very extensive osteitis and osteomyelitis. The bone marrow was in a fibrous state in some areas; in other parts, granulomatous lesions were noted. A large number of leukocytes

FIG. 1

G. C., a woman, aged fifty-three years, had chronic strain of the right tibial collateral ligament, with an osseous deposit at the femoral attachment of the ligament and advanced degenerative changes of the medial aspect of the right knee joint, resulting from thirty-one years of figure skating. (Illustration reversed.)

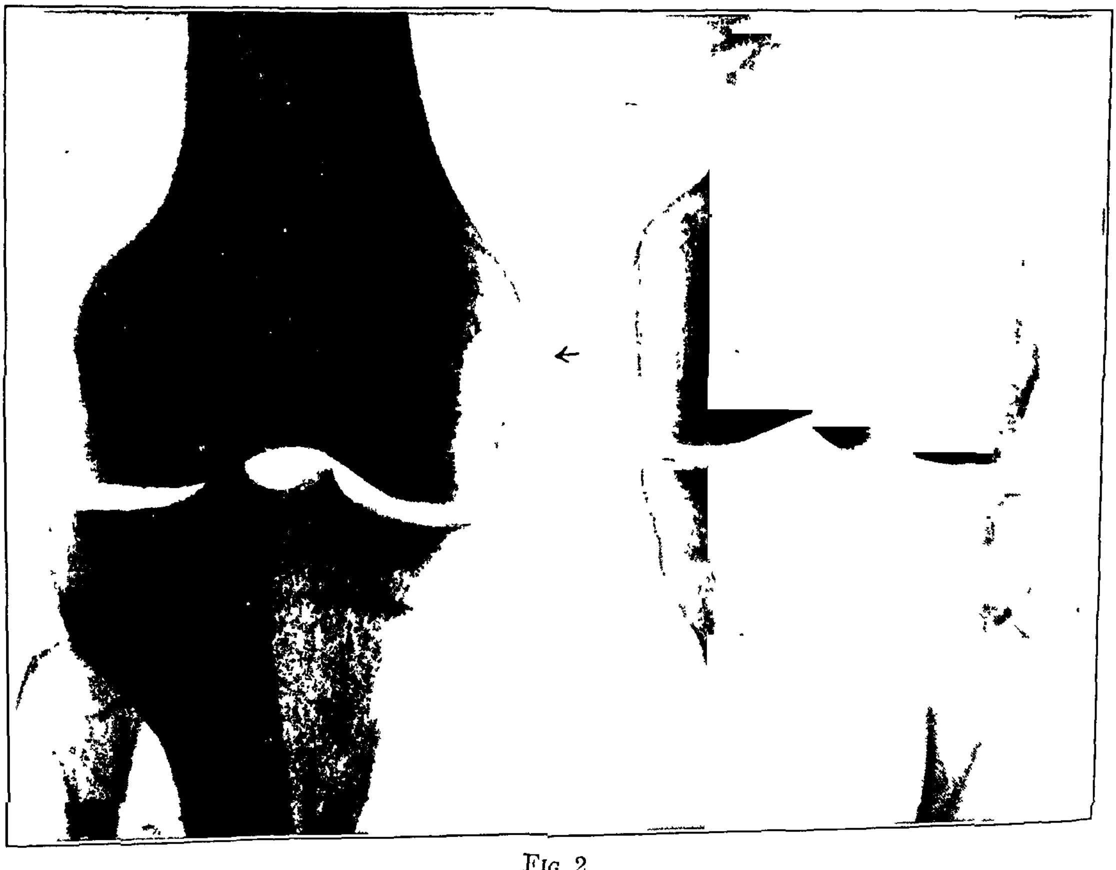

FIG. 2

I. C., a woman, aged forty-two years, had chronic strain of the right tibial collateral ligament with an osseous deposit in the ligament (Pellegrini-Stieda disease), resulting from twenty-seven years of figure skating.

were present. It is evident, therefore, that the lesion in the bone marrow was inflammatory in nature and due to an infection by *Salmonella typhimurium*.

Other Cultures: Cultures of faeces and urine and of throat and pharyngeal secretions failed to disclose the presence of *Salmonella typhimurium*, although a special search for this organism was undertaken and repeated examinations were made. The spinal and pleural fluids, likewise, did not harbor the Salmonella organism and proved to be sterile on culture.

Widal Test: The antibody response of the patient was studied by means of the Widal test. A serum specimen, obtained on September 8, showed no agglutinins in titers of 1 to 20 and above, against typhoid, paratyphoid A, paratyphoid B, Proteus, and Brucella organisms. On September 17, agglutinins could be demonstrated; strong agglutination was obtained with a suspension of paratyphoid B. The titer of agglutinins of the serum against the patient's own strain was 1 to 400, and this was unchanged on September 19. On October 29, the agglutinin titer had increased to 1 to 800. It is evident, therefore, that during the course of the illness specific antibodies were developed in a fairly high titer.

Blood Examination: On September 2, 1945, the following blood findings were obtained:

Red blood cells	2,130,000
Hemoglobin	6 grams per 100 cubic centimeters
White blood cells	6,700
Polymorphonuclear neutrophils	
Adult forms	56 per cent.
Young forms	20 per cent.
Lymphocytes	22 per cent.
Monocytes	2 per cent.

During the course of the illness the anaemia slowly disappeared, and the hemoglobin reached a level of 14.5 grams by the time of discharge. The leukocyte count increased to 10,700 on September 6 and reached a maximum of 19,950 on September 19. It became normal on October 16 and remained so until the time of discharge.

Urine Examination: During the entire period of hospitalization, numerous urine specimens were negative for albumin, sugar, and cellular elements.

In summary, then, it may be stated that this child, two and one-half years old, was suffering from septicaemia, caused by *Salmonella typhimurium* and complicated by osteomyelitis of most of the ribs, the scapula, pelvic bones, and femur. Complete recovery took place. It is noteworthy that there was no sequestration in any of the lesions, and that the architecture of the bones returned to normal much more rapidly and completely than in the ordinary case of osteomyelitis caused by the Staphylococcus. Leukopenia was present at the onset of the illness. Agglutinins developed in fairly high titer (1 to 800) against the offending organism. Salmonella organisms were not recovered from the faeces, urine, or pharyngeal secretions.

DISCUSSION

In human beings, Salmonella organisms may produce three different clinical syndromes,—namely, (1) Salmonella fever, resembling typhoid fever; (2) Salmonella gastroenteritis, or food poisoning, and enterocolitis; and (3) Salmonella septicaemia. In Salmonella septicaemia, metastatic lesions may develop in various organs of the body. According to the literature, hematogenous osteomyelitis and arthritis are of relatively rare occurrence. In a review of the reports on Salmonella infections of bones and joints published up to 1940, Guerra, Peluffo, and Aleppo collected only fifteen proved cases. Several other cases have been described or mentioned briefly in various communications, but are not included in the review of Guerra and his associates. For example, in 1925, Ssokoloff described surgical complications of paratyphoid Erzinjan infections; and reported twelve instances of osteomyelitis. Leveuf and his associates refer to seven such cases, reported in the French literature between 1913 and 1928. Still other cases may have been observed but not reported. In view of the repeated finding that Salmonella osteomyelitis often is a relatively mild disease that may improve without surgical intervention, it seems fair to assume that such cases may have escaped diagnosis. In the future, it may be wise to examine roentgenographically the skeletons of patients suffering from Salmonella septicaemia, in order to determine the true incidence of Salmonella osteomyelitis.

sport in strenuous form. As long as the stress is continued, the ossifications become progressively larger, with the result that the attached ligaments and tendons are strained more easily and more severely, and the strains remain longer. With discontinuance of stress, the strains gradually disappear; but the ossifications usually remain,—ready to cause trouble if stress is reapplied.

When these ossifications are present, a short period of skating and the use of checking movements may cause such severe pain that the skater is unable to continue, and is often compelled to hold the knee as if paralyzed. If the stress is avoided for several days, the severe pain and disability tend to disappear, leaving a residual soreness and stiffness which may persist for several months. For this condition, roentgenotherapy has been found most effective.

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AN EFFICIENT DUAL-PURPOSE RETRACTOR

BY LIEUTENANT COLONEL PETER-CYRUS RIZZO

Medical Corps, Army of the United States

Proper tissue retraction is essential to successful and expeditious surgery. Most retractors are mechanically unsound, as a shift of position tends to disengage them.

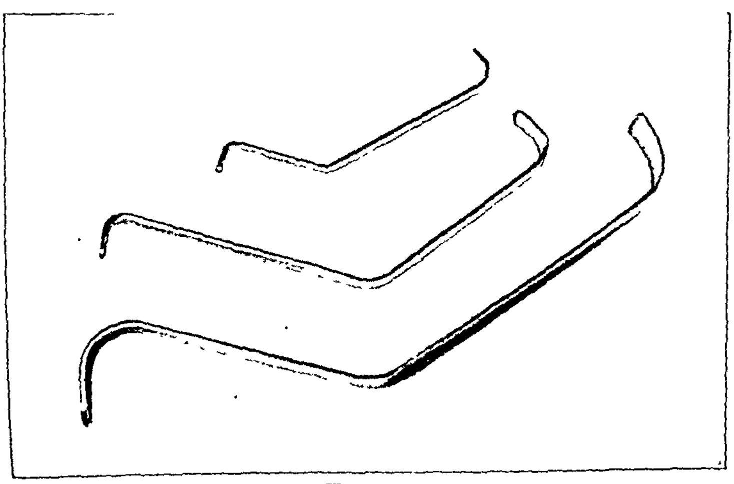

Fig. 1

The principle of the retractor described here lies essentially in the 45-degree angle of the handle and in the shaping of the handle end. The angulation allows transmission of force and pull to the tip, or toe, of the retractor. The ordinary retractor transmits the pull to the heel, and thereby predisposes to slipping and loss of effect. The handle ends are so shaped (Fig. 1) that they can be used for retraction or for isolation of bone or soft tissue. The angle is placed approximately four inches from the heel in the large retractor and one and one-half inches from the heel in the small retractor. The smallest size is most useful in surgery of the hand or of the small parts; the largest size has no limitations, depending upon the length of the foot, or claw end.

There were no palpable organs or masses. The right knee was held in 90 degrees of flexion, and was mildly tender to anterior pressure over and around the patella. Extension of the knee produced considerable pain. No local heat or discoloration was present. The circumference of the right knee was twenty-four centimeters and that of the left knee was twenty-two centimeters. A definite, marked effusion was present in the right knee joint. The skin was slightly excoriated,—probably the result of heat applied over the joint by the parents; the extremities were otherwise normal. The reflexes were physiological. No paralysis or anaesthesia could be demonstrated. The cranial nerves were intact.

Roentgenograms showed no pathological changes of the bones, but soft-tissue swelling was noted.

The laboratory findings were as follows:

April 7, 1945	
Red blood cells	4,300,000
Hemoglobin	11.4 grams
White blood cells	10,050
Polymorphonuclear neutrophils	53 per cent.
Monocytes	5 per cent.
Lymphocytes	41 per cent.
Eosinophils	1 per cent.

A tuberculin test, in which 0.1 cubic centimeter of a purified protein derivative was employed, was negative.

April 14, 1945	
White blood cells	19,050
Polymorphonuclear neutrophils	61 per cent.
Lymphocytes	39 per cent.
Blood Kahn test	Negative
Blood culture	Negative
May 2, 1945	
Red blood cells	4,250,000
Hemoglobin	9.7 grams
White blood cells	8,250
Polymorphonuclear neutrophils	27 per cent.
Lymphocytes	72 per cent.
Monocytes	1 per cent.
Urinalysis	
Appearance	Clear
pH	6.0
Specific gravity	1.013
Albumin and sugar	0
Microscopic appearance	Normal

On May 3 and 4, stool examinations were negative for Salmonella organisms. Salmonella species (Montevideo type) grew in the fluid which had been aspirated from the knee. Blood agglutination against the organism found in the knee fluid was complete in dilutions of 1 to 80 and 1 to 160; it was partial in dilutions of 1 to 20, 1 to 40, 1 to 320, and 1 to 640.

Course: During the first week, the temperature remained at about 100 degrees. It rose to 104 degrees at the end of the week, remained high for three days, and fell to normal by lysis in the next two weeks. The fluid in the knee joint was aspirated on April 21, and again on April 24. About twenty-five cubic centimeters of amber-colored fluid was obtained on each occasion. Penicillin was started on April 10, before the exact diagnosis was known, and given in a dosage of 10,000 units every three hours until April 24. On April 24, sulfadiazine was given, because the organism proved slightly sensitive to this drug in the laboratory. The child was given thirty grains of sulfadiazine daily until May 5. The knee became less swollen, and the range of motion gradually increased until normal motion was restored. In all probability, the drug therapy did not influence the recovery.

The organism was a non-spore-forming, gram-negative rod, identified as Salmonella species (Montevideo type) by its fermentative reaction on the different carbohydrates.

There have been seventeen known outbreaks of Salmonella infection of the Montevideo type in the United States, but no other report has been found of knee-joint involvement.

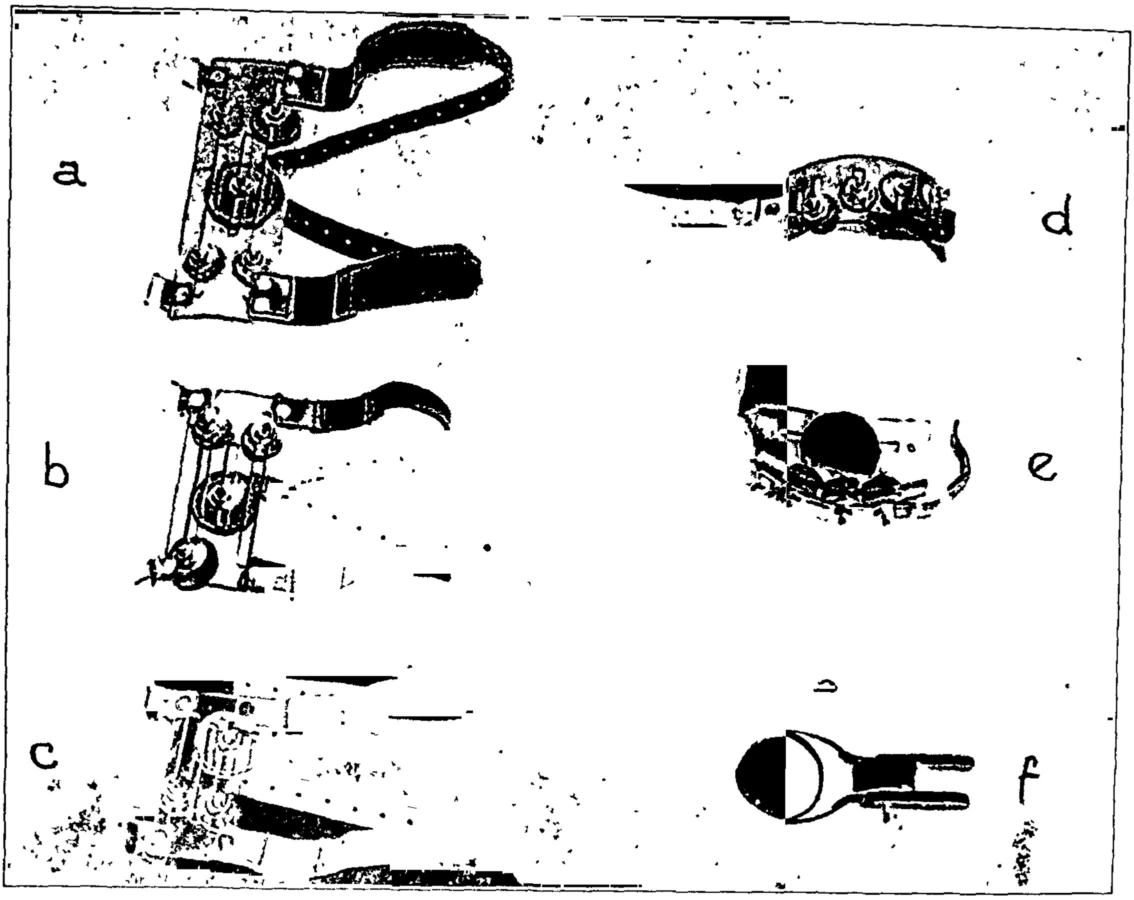

FIG. 2

Electrode holders with the electrodes in place: *a*. For sciatic, peroneal, and posterior tibial lesions. *b*. For median-nerve injuries, proximal muscle group. *c*. For ulnar nerve injuries, proximal muscle group. *d*. For radial-nerve injuries. *e*. For ulnar-nerve injuries, distal group. *f*. For median-nerve injuries, distal group.

This gives fairly accurate stimulation and, when consistently applied, the desired effect is obtained. This would indicate that, for practical purposes, the benefit arises from stimulation of the muscles to a maximum, whether separately or together; the stimulation of the antagonists should be avoided.

DESCRIPTION OF APPARATUS

The individual stimulator should be small, simple, inconspicuous, light, and with sufficient power to correspond to the stimulation previously applied. Through a series of models, one has finally been produced which meets most of these requirements. It consists of a small galvanic generator with a dry-cell battery (Fig. 1). Time and strength of the stimulus are controlled by adjustable switches. Intensity of the current may be regulated for arm or leg muscles. The current flow may be reversed by a polarity switch. The machine is shaped so that it may be carried in the trousers or tunic pocket with the electrodes applied to the desired area. The electrodes are of the usual construction, with two layers of one-quarter-inch white felt covering copper plates. They vary in size from five-eighths of an inch to one and one-half inches (Fig. 3). The electrodes are held in oblong plates of plexiglass, molded to fit the extremities (Fig. 2). These electrode holders have linear slots along which the electrodes may be moved to the points of maximum response. The holders are transparent to facilitate the accurate adjustment of the electrodes over motor points.

METHOD OF APPLICATION

The patient may be quickly and simply instructed in the application of the stimulator. He is taught to adjust the electrodes properly and to apply them over the paralyzed

FIG. 2

Roentgenogram taken February 20, 1946, showing the ischium after the removal of the fragment.

FIG. 1

Roentgenogram, taken on January 21, 1946, showing the ununited epiphysis of the left ischium.

FIG. 5
Application of the electrodes for stimulation to the median proximal group of muscles.

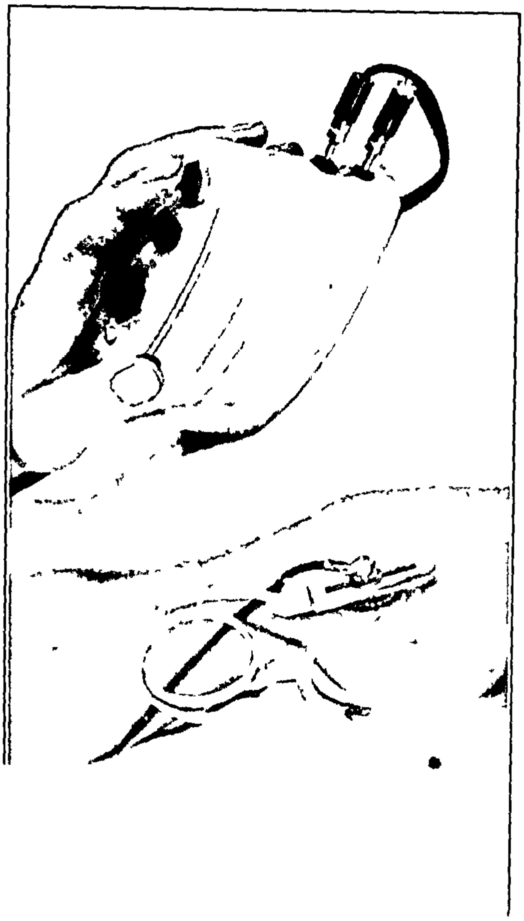

FIG. 6
Showing method of stimulating median distal group.

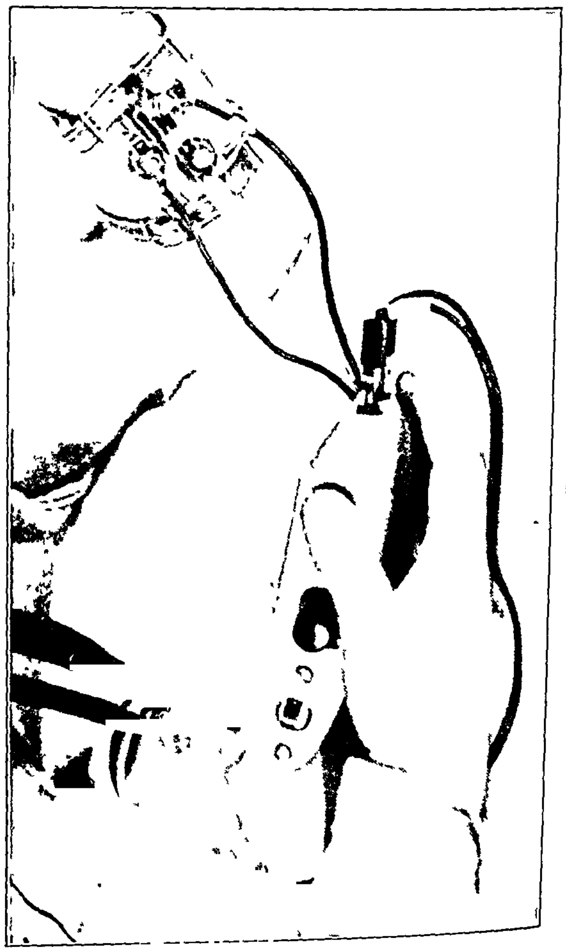

FIG. 7
Showing application for ulnar proximal group.

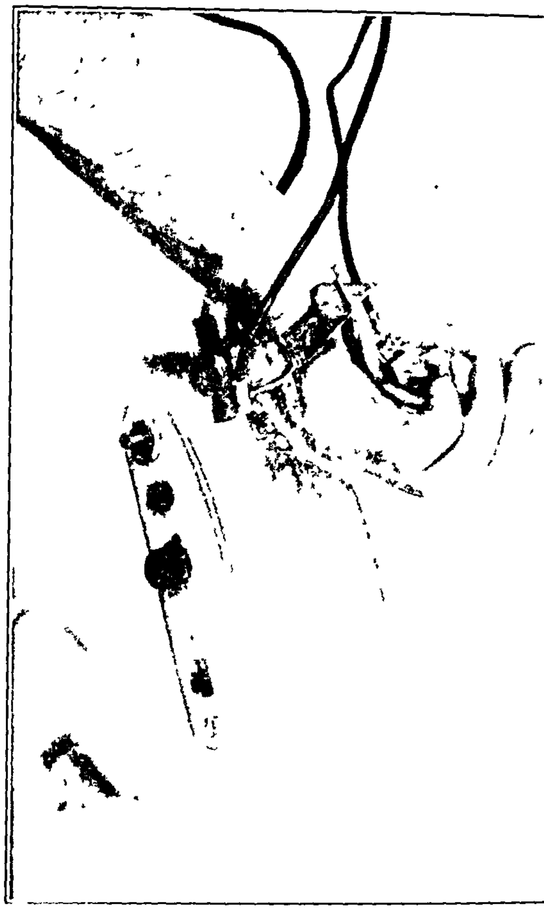

FIG. 8
Application of

OSSIFICATIONS ASSOCIATED WITH CHRONIC STRAIN OF THE TIBIAL COLLATERAL LIGAMENT FROM ROLLER-SKATING

BY EDMUND W. KLINEFELTER, M.D., YORK, PENNSYLVANIA

Although roller-skating is a very popular sport and injuries resulting from it are frequent, practically nothing concerning them has appeared in the medical literature.[2] Over the past thirteen years, many patients with these injuries have been referred to the author for examination and treatment. The most frequent and most interesting injuries have been acute and chronic strains of the tibial collateral ligament of the knee, associated with ossifications.

Chronic strains of the upper half of the tibial collateral ligament, which often occur among football players and skiers[3], do not result from the usual skating movements, but are produced by such movements as the "split" in figure skating. Subsequent to these strains, ossifications may develop in this part of the ligament (Fig. 1). Similar ossifications, resulting from causes other than roller-skating, have received considerable discussion under the heading of Pellegrini-Stieda disease[1] (Fig. 2). They have, in principle, the same significance and require the same treatment as those in the lower half of the ligament.

Since the stress in roller-skating is applied more to the lower half of the ligament, strains resulting in ossifications are more frequent in this portion than in the upper half. In addition, ossifications appear also at the strained tendon attachments of the popliteus and soleus muscles, on the medial aspect of the tibia. These ossifications frequently produce symptoms and may interfere seriously with the function of the attached ligament and tendons. Therefore, they are important; but no report concerning them could be found.

Because of the stress from an added load and ill-adapted movements, these chronic strains with ossifications are especially predisposed to develop in the obese woman with a square torso, protruding abdomen, and relatively long, thick legs, as she advances beyond the age of thirty-five years. This woman usually lacks ease and grace on the crowded rink. In order to avoid collisions with other skaters, she is compelled to check her advance frequently, not by the turning and gliding movements characteristic of the younger, better-developed skater, but by throwing her weight on the inside wheels of the externally rotated skate as it is dragged against the floor; the same leg is practically always used for this purpose. Tremendous stress is thereby placed on the tibial attachments of the tibial collateral ligament, and of the popliteus and soleus muscles.

The development of the strain is gradual; the first symptoms rarely appear before at least three years of skating. Early in the development of the strain, the skater may notice slight pain in the knee, with perhaps a slight feeling of rubbing, and at times audible creaking on movement. The day after a period of skating the knee may feel somewhat stiff, but this stiffness tends to disappear. Physical examination may disclose slight tenderness over the tibial attachments of the tibial collateral ligament and the popliteus and soleus muscles, slight limitation of flexion, and pain localized to the ligament and tendon attachments upon passive abduction of the leg at the knee. A roentgenogram may show the swollen ligament (Fig. 3). After several days of rest, all symptoms usually disappear.

Frequently the skater herself discovers that the checking movements cause trouble, and she avoids them. In any case, the importance of avoiding these movements must be impressed upon her. Moreover, it is well to recommend a shorter, slower skating stroke, and limitation of the total skating period to not over one hour per week. If these recommendations are not observed, bony deposits, visible on the roentgenograms, often begin to appear at the region of the tibial attachments of the tibial collateral ligament and of the popliteus and soleus muscles (Fig. 4).

These deposits represent an additional warning sign against a continuation of the

RESULTS

1. The apparatus as outlined has been used on 150 patients and has functioned satisfactorily. A single battery will last five to seven months.
2. The apparatus is simple enough for the average patient to operate, and patients have displayed considerable intelligence in its application. Proper placing of the electrodes, the exact stimulus necessary, and the response that should be obtained are quickly learned.
3. The apparatus permits hourly treatment, instead of an irregular period every second or third day.
4. Patients may be discharged from the Hospital earlier, thus relieving the problem of accommodation. Readjustment and return to gainful occupation are facilitated.
5. The load of an overworked physiotherapy department has been lightened considerably.

CONCLUSIONS

The prospect of allowing the patient to treat himself was approached with hesitation, since carelessness, poor mentality, and lack of cooperation might spoil the whole plan. These fears have been groundless, because the more active participation under supervision has increased the patient's interest and cooperation. The danger of placing electrical therapeutic apparatus in the hands of the patient has been appreciated, and the unit has been constructed so that the patient cannot possibly do any real harm. The experiment has shown that proper electrical stimulation of muscles can be simply applied and continued for long periods by the average patient.

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FIG. 3

D L., a woman, aged forty-eight years, had chronic strain of the left tibial collateral ligament. Roentgenogram shows the swollen ligament, resulting from five years of frequent checking movements. Osseous deposits on the medial side of the right knee resulted from twenty-eight years of figure skating.

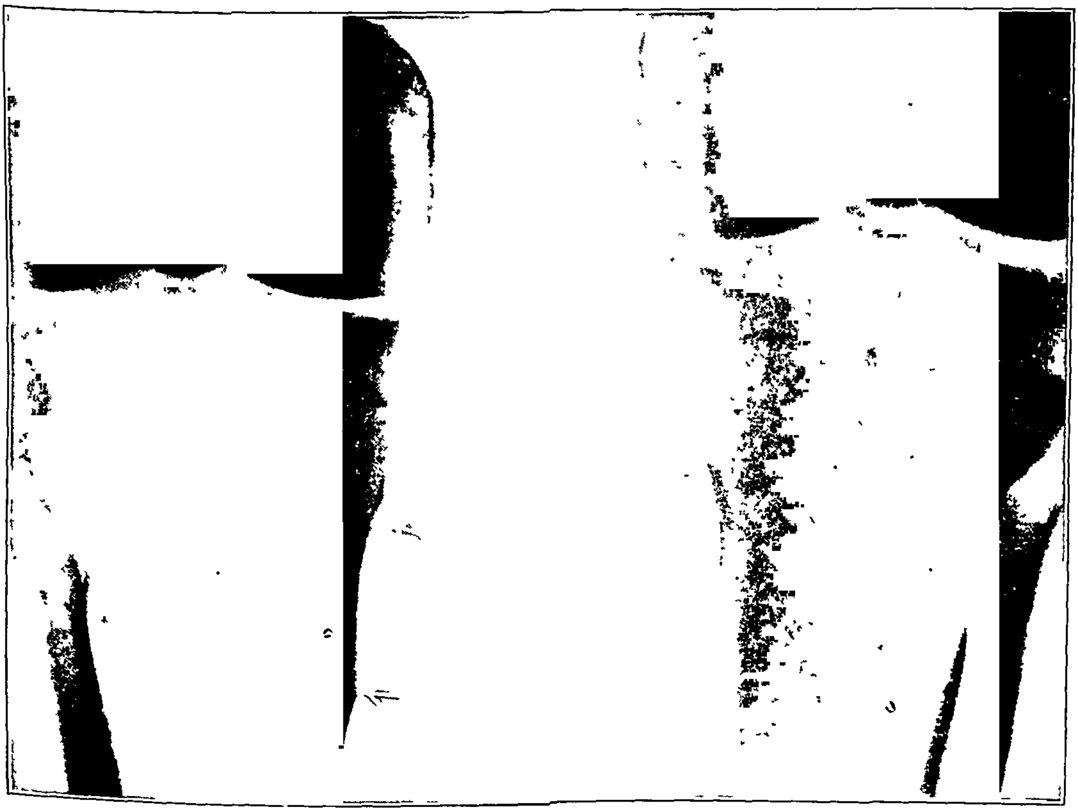

FIG. 4

D T., a woman, aged forty-four years, had chronic strain of the right tibial collateral ligament and the tendons of the popliteus and soleus muscles, with osseous deposits at their medial tibial attachments, resulting from twelve years of frequent checking movements in roller-skating.

MODIFICATION OF THE DENIS BROWNE SPLINT

BY MICHAEL BLUHM, M.D., MEMPHIS, TENNESSEE

From the Campbell Clinic, Memphis

The most serious objection to the use of the Denis Browne splint in the treatment of congenital talipes equinovarus has been the difficulty of obtaining correction of the persistent adduction of the fore part of the foot[4]. It has long been recognized that this component of the deformity must be completely corrected before any attempt is made to correct the equinus.

Scarpa, as quoted by Adams, described a short leg brace with straps, which was used for maintaining position after operative correction of the club-foot deformity. Adams modified this by dividing the foot plate transversely, so that the mechanical center of motion corresponded with the mid-tarsal joint of the foot, this being the anatomical center of motion of the fore part of the foot with adduction deformity.

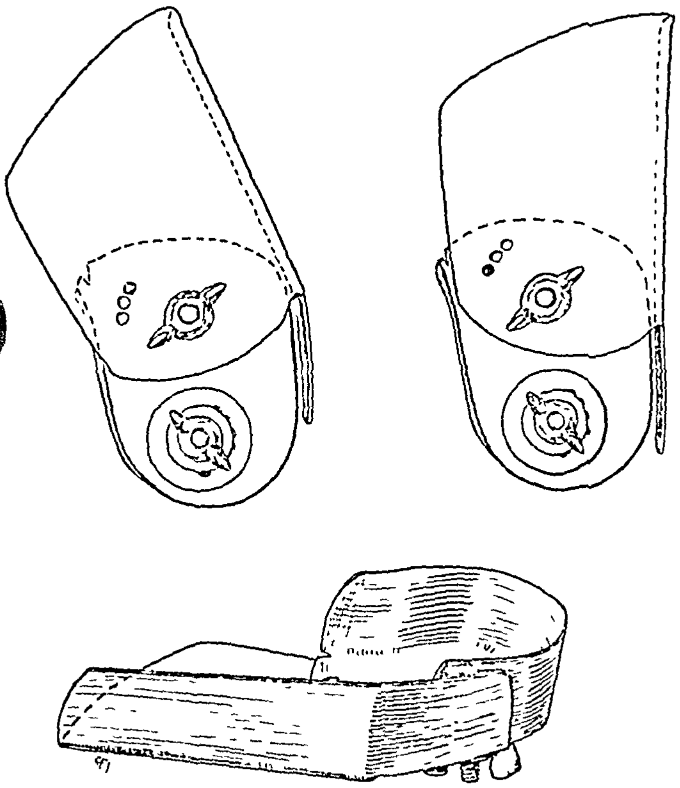

FIG. 1

This principle has been applied by the author to van Domselaar's modified foot plate of the Denis Browne splint, and it has been of definite value in obtaining correction of the adduction deformity of the fore part of the foot.

The foot plate (Fig. 1) is constructed in two parts,—a heel plate and a toe plate. The toe plate rotates freely in a transverse plane on a threaded axis pin of the heel plate. The pin is placed so that the axis of rotation corresponds to the center of the mid-tarsal joint. The degree of rotation is controlled by a series of holes in the toe plate and by a second pin on the heel plate. The flange on the inner side of the toe plate is extended backward, so that no defect will be present on the medial aspect of the foot plate which might allow window oedema to occur. This flange is malleable, and can be curved to conform to the shape of the medial aspect of the foot as the plate is gradually rotated externally. The sole of the splint is lined with white felt, and the flanges are lined with sponge rubber.

Farill has recently described a similar modification, using a worm screw to control the external rotation of the splint.

The treatment of talipes equinovarus by this modified plate is carried out in a manner similar to that outlined by Thomson, with the exception that the varus of the fore part of the foot is gradually corrected by the simultaneous external rotation of the toe plate, as well as by the external rotation of the entire plate itself on the cross bar.

NOTE: Mr. W. H. Broughton, foreman of the brace shop at Campbell Clinic, assisted in planning this foot plate, and also constructed it.

A MINIATURE GALVANIC STIMULATOR

BY JAMES E. BATEMAN, M.D., TORONTO, ONTARIO, CANADA

From the Division of Orthopaedic Surgery, Christie Street Hospital, Toronto

The value of electrical stimulation in nerve injuries has frequently been questioned. However, during the recent War, such reports as those by Solandt and associates, and Gutmann and Guttmann have appeared as strong recommendations.

From these experimental and clinical investigations, it may be concluded that definite changes occur following electrical stimulation of denervated muscle. Histologically, it is evident that, by minimizing atrophy, the serious damage at the motor-end plate is decreased. It has become apparent that diminished atrophy and all its associated benefits may be expected only when treatment is applied early, at frequent intervals, and for a prolonged period. Electrical stimulation will not entirely prevent damage in denervated muscle; but, if it is instituted early and given frequently, the muscle will be preserved in as near to the ideal condition as possible.

The application of the principle of adequate stimulation in a large group of patients with nerve lesions has proved difficult, chiefly because of limitations of staff, space, and equipment. The accommodation alone of such patients, even in a large center, is difficult, and attendance at the Physiotherapy Department becomes unsatisfactory. This crowding and confusion has resulted in patients receiving a short period of treatment once every two or three days. Irregular and infrequent stimulation cannot be expected to minimize the damage of denervation significantly. Moreover, one is reluctant to keep a patient under full hospital surveillance for many months, in order to give treatment lasting only a few minutes each day. The earlier the patient can be returned to his occupation, the better. Also, despite the merits of the case, commercial firms and employers are reluctant to allow a man an hour a day from his job for several months. If the patient can carry on at his job, receiving adequate therapy without time loss, rehabilitation is accelerated. To meet such difficulties and at the same time to increase the amount of therapy, experiments were undertaken to produce a small pocket-size stimulator which the patient might wear and use himself, reporting at frequent intervals for supervision.

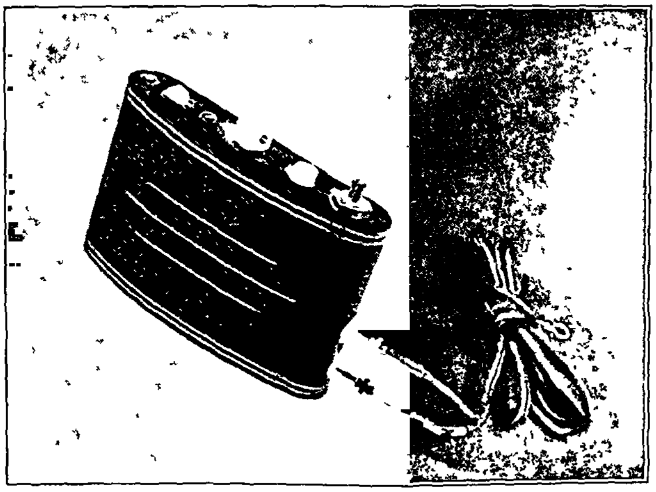

FIG 1

The pocket-size electrical unit. The controls are all on one panel to make possible operation with one hand.

THE TECHNIQUE OF STIMULATION

Galvanic current has proved the most satisfactory and practical means of stimulating denervated muscle. Sinusoidal or surging current is excellent, but not all patients respond to such stimulation. For maximum results from galvanic stimulation, small electrodes should be placed on either end of the muscle, and each electrode shifted when a new muscle is to be stimulated. While such a technique has always been prescribed, investigation has shown that it is rarely carried out carefully. Invariably, treatment consists in using a large indifferent electrode with a small point stimulator to pick out the individual muscles.

A REVIEW OF THE EVOLUTION OF THE ORTHOPAEDIC BRANCH OF SURGERY IN NEW YORK CITY

BY ROYAL WHITMAN, M.D., NEW YORK, N. Y.*

This review of the evolution of orthopaedic surgery properly begins with its christening by Valentine Mott in 1841.

He defined it as the "combination of operative with mechanical surgery, which had inaugurated a new and illustrious era in the healing art". This forecast has been amply justified; but, since the surgery of the combination was restricted to the subcutaneous division of contracted tissues in the correction of deformity, the "meridian splendor of its development", which he acclaimed in his own day, was deferred for many years,—until surgery in a comprehensive sense had become the dominant factor in its title, and the operative reconstruction of disabled members its distinctive feature.

Of those directly involved in Mott's pronouncement, Sayre, the only surgeon of the group, has been aptly termed its forerunner, since, as the first Professor of Orthopaedic Surgery, he included fractures, dislocations, and clinical surgery in his official title.

Knight, Davis, and Taylor, the upholders of the established practice, had each contributed a variant on the treatment of tuberculous disease of the hip and spine, then by far the most important constituents of orthopaedic practice. Thus they were at odds with Sayre in principle, and with each other in practice.

This was a period when, according to Holmes, "the atmosphere was vocal with the flippant loquacity of half-knowledge",—a characterization amply illustrated by the pioneers.

Sayre claimed that his subperiosteal resection of a tuberculous hip joint permitted reproduction of the bony structure, and thus the restoration of motion and stability in locomotion.

Davis claimed that his method of constant elastic extension actually separated the articulating surface of the hip joint, and thus, by permitting "motion without friction" during the period of repair, conserved the function of the joint and the nutrition of the limb.

Taylor claimed that his "jointed spinal assistant" checked flexion and pressure at the seat of disease; yet, by permitting voluntary extension of the spine, it utilized muscle action to restrain and to reduce deformity.

Knight rejected these "adventurous" expedients of his colleagues in favor of surgico-mechanics and "expectancy", supplemented by enforced bodily activity to prevent the "etiolation consequent upon continued repose". He claimed that under this system 75 per cent. of the "ordinary conditioned patients laboring under synovitic disease were restored to self-sustaining ability".

It may be noted that these divergent methods were based on the mutually accepted principle that persistence in motion of a diseased joint, voluntary or enforced, was the essential preventive of ankylosis. Thus the local controversialists were united in their opposition to Thomas, the exponent of prolonged, uninterrupted rest as the basis of natural repair and, therefore, of conservation of function.

In 1887 the contentious pioneers and their associates, thirty-four in number, pooled their issues in organizing The American Orthopaedic Association. This event, from the evolutionary standpoint, was of almost equal importance to the christening, since it involved the question of identity. Whether its qualification as a specialty should be the means employed in treatment, or whether, as the representative of a new era, it was to be free from the restrictions associated with its ancient name,—this vital decision entailed an internecine conflict that lasted throughout the century.

* This article was submitted to *The Journal* by Dr. Whitman a few days before his death in August 1946. —*Editor.*

muscles at the points of maximum stimulation. These points are marked for him by the physiotherapists. If he has difficulty in finding the proper areas, they may be marked by small brown tattoo points.

He is taught to place the extremity in the relaxed position (Fig. 4), to adjust the

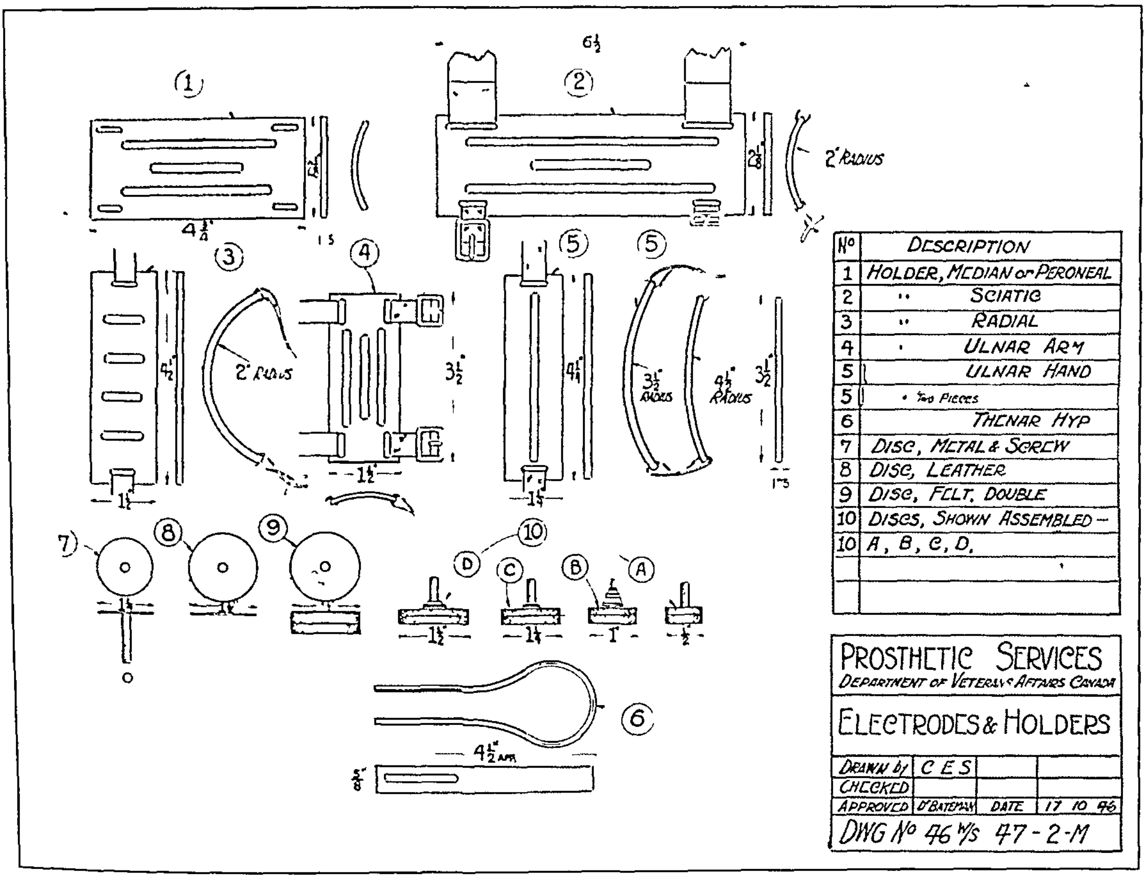

FIG 3

Engineer's drawing, showing construction of the electrodes and the electrode holders.

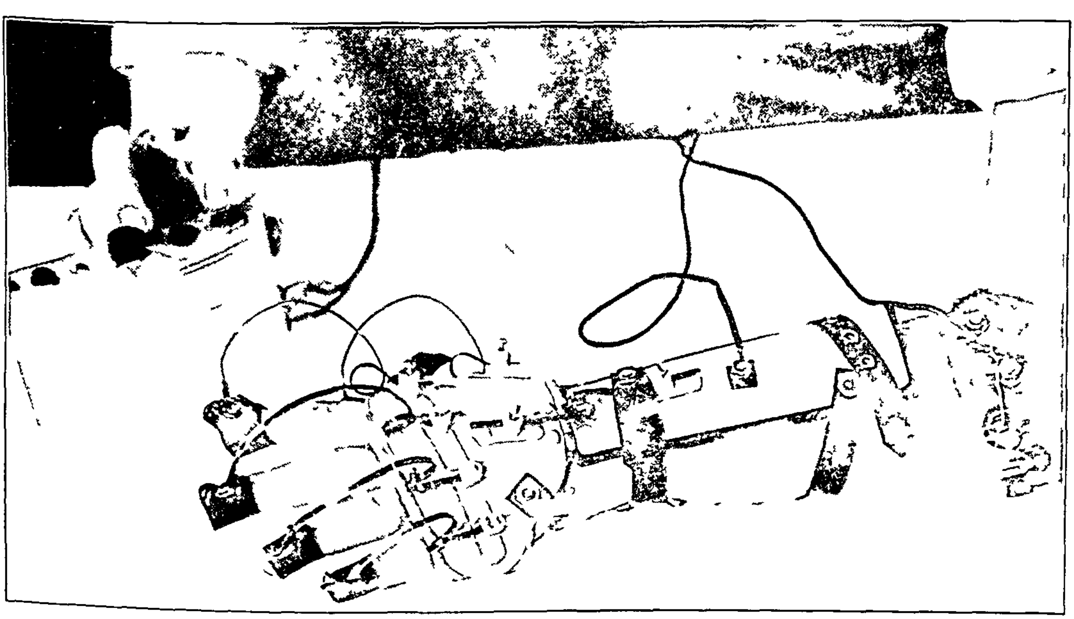

FIG 4

The apparatus as applied to a hand splint in a case of radial-nerve paralysis Note that the hand is placed in the relaxed position for treatment.

The leader of the progressive party during this preliminary period was Virgil P. Gibney, who was born and bred in the genial atmosphere of Kentucky. He completed his medical course at Bellevue, where he listened to the lectures of Sayre, whom he termed "that giant of Orthopaedic Surgery". Yet, immediately upon his graduation in 1871, he joined the staff of the Hospital for the Ruptured and Crippled, and remained as Knight's resident assistant for thirteen years.

On his dismissal, he took that opportunity "to brush up a bit" by visiting clinics in England and Scotland. He was particularly impressed by Thomas; although, as a convert to the traction method, he could hardly accept the conclusion that "it involved a fractional degree of fixation, sufficient to mask the evil of a ridiculous malpractice". On his return to New York, he began a private practice, in which he was immediately successful.

He joined Shaffer in the organization of The American Orthopaedic Association and was elected Chairman at its first session. In his representative capacity, he disclaimed "any intention to deny to any of his fellow members a special predilection for apparatus alone or for apparatus combined with minor operations or for operations alone". On the contrary, he invited all factions to unite in the establishment of a solidarity essential to the recognition of the nascent specialty.

In the same year, upon Knight's death, Gibney was appointed his successor and began at once what was to be his most important contribution to consistent progress,—namely, the transformation of a home for crippled children into a hospital, prepared in its professional and physical equipment to demonstrate the normal development of the orthopaedic branch of surgery. For this life-long task, Gibney had unusual qualifications. His long association with the Hospital assured the cooperation of the trustees in meeting the constantly increasing expense that the changes involved. He had, furthermore, the great advantage of building on Knight's foundation of surgicomechanics; free, therefore, from the artificial restrictions of departmental clinics and the physical limitation of hospitals for children.

Thus Knight, unwittingly, and Gibney, by intention, qualify as purveyors of evolution. In Knight's day, the two departments of the Hospital, although served by the same Staff, were practically distinct from one another. The majority of the indoor patients were "laboring under synovitic disease" and as the purpose of treatment was "to restore them to self-sustaining ability" the yearly admissions averaged less than 200. The out-patient department was far more important, since it carried out the main purpose for which the Hospital was incorporated,—namely, "to supply trusses, spring supports, bandages, laced stockings, and other suitable apparatus for the relief and cure of cripples, both adults and children, and to make these benefits available to the poorest in the community".

Gibney's first innovation on the established order was to improvise an operating room, although, to quote from the history of the Hospital, "at the age of forty he had had no experience in operative technique". This may have been an advantage in influencing his appointments to the Staff,—notably, that of Bull, a leading surgeon who was placed in charge of the Hernia Department.

As a recent recruit to surgery, Gibney, free from hampering preconceptions and personal prejudice, encouraged enterprise in his assistants and provided opportunity for its development. At this time, orthopaedic operations were, as in Mott's day, chiefly of the subcutaneous type and purely corrective in scope.

In 1929, when the physical development of the Hospital was fairly complete, 3522 operations were recorded. Of these, 1875 were classed as orthopaedic, and 1647 were credited to the Hernia Service. Thus, in the interval, the Hospital had become the leading exponent of constructive surgery, both for the ruptured and the crippled, confirming after many years Sayre's title of forerunner of a new era. Furthermore, under the impelling force of operative surgery, the Service had undergone radical reconstruction, in which its constituent factors had been expanded and coordinated to represent a progressive branch

Fig. 9
Application for sciatic and posterior tibial groups.

Fig. 10
Stimulation of peroneal group through plaster.

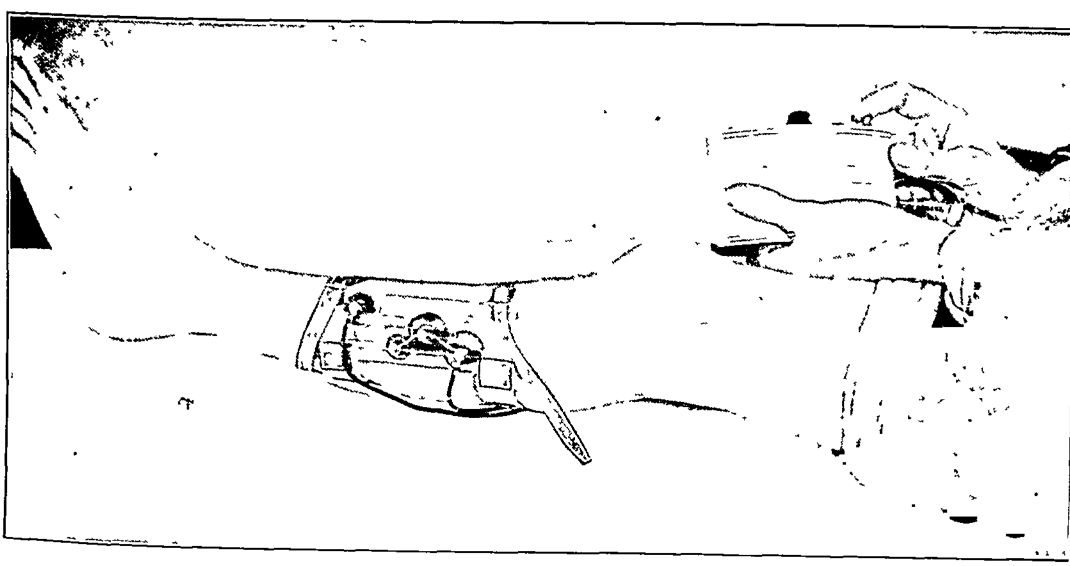

Fig. 11
Application for peroneal group out of plaster.

current until the desired response is obtained, and to avoid stimulating the antagonists. For maximum benefit, stimulation should be carried out hourly, producing ten to fifteen contractions of the paralyzed muscles. The stimulator may be easily carried in a pocket and the electrodes worn continuously, or, if the patient prefers, the electrodes may be carried and applied only for treatment. The electrodes are removed at night and allowed to soak in a weak saline solution. They are then ready for application the following day and will remain moist during the day.

News Notes

The deadline for receipt of applications for Part I of the examinations of **The American Board of Orthopaedic Surgery** has been established as February 1, 1947.

Correspondence and applications should be forwarded to Dr. Francis M. McKeever, Secretary, 1136 West 6th Street, Los Angeles 14, California.

The National Society for Crippled Children and Adults, Inc., will hold its usual sale of Easter Seals. The purchase of these seals will help this important work. They may be obtained in quantities from The National Society for Crippled Children and Adults, Inc., 11 South La Salle Street, Chicago 3, Illinois.

Announcement has been made of the formation of the **Sociedad Peruana de Ortopedia y Traumatología,** with headquarters in Lima, Peru. The purpose of the society is to encourage the study of the affections and traumata of the locomotor apparatus in all their aspects,—clinical, biological, surgical, and social. The President of the society for the current year is Dr. Oscar Guzmán, of Lima.

On October 12, 1946, the **New Jersey Orthopaedic Society** was organized at a meeting in Long Branch, New Jersey, with nineteen founder members, each of whom is a Diplomate of the American Board of Orthopaedic Surgery.

The following were elected to office:

President: Leopold Szerlip, M.D., Newark
Vice-President: Harold W. Smith, M.D., Orange
Secretary-Treasurer: Raphael R. Goldenberg, M.D., Paterson.

The National Foundation for Infantile Paralysis, Inc., announces the publication of a series of muscle charts. Under the direction of the committee on the treatment and after-effects of poliomyelitis, charts have been prepared giving a standard type of record of muscle strengths. These can be used advantageously in the care of poliomyelitic patients by the physical-therapy departments of hospitals and clinics. They are available, free of charge and in quantities, and may be obtained from The National Foundation for Infantile Paralysis, Inc., 120 Broadway, New York 5, N. Y.

INTERNATIONAL SOCIETY OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY

The meeting of the *Société Internationale de Chirurgie Orthopédique et de Traumatologie* was held in Brussels, October 2, 3, 4, and 5, 1946, under the presidency of Dr. L. Ombredanne, of Paris. An interesting program was presented, with speakers from many different countries. Officers for the coming year were elected, as follows:

President: L. Ombredanne
Vice-Presidents: R. San Ricart and Harry Platt
Secretary-General: J. Delchef
Treasurer: C. Parisel.

Dr. Henry W. Meyerding, of Rochester, Minnesota, who attended the meeting as the delegate from the United States, was elected President of the next Congress, which will be held in Amsterdam, Holland, in the fall of 1948.

While Dr. Meyerding was abroad, he gave lectures at the Universities of Leiden, Amsterdam, and Edinburgh. He addressed the Society for Furtherance of Physics, Medicine and Surgery, in Amsterdam and the Société Française d'Orthopédie, in Paris. He also attended the 49th Congrès Française de Chirurgie, where he was elected to honorary membership in the Académie de Chirurgie Française which held its hundredth anniversary meeting in 1946.

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The British Orthopaedic Association was held in London, October 18 and 19, 1946.

Mr. George Perkins, President of the Association, opened the meeting with a discussion on "Fractures of the Os Calcis". Mr. Norman W. Roberts and Mr. W. Sayle Creer had each followed up scores of cases over several years and had independently reached similar conclusions concerning compression

AN IMPROVED RETRACTOR FOR INTERVERTEBRAL-DISC SURGERY

BY MICHAEL SKOVRON, M.D., ERIE, PENNSYLVANIA

Most surgeons who do intervertebral-disc surgery will agree that an adequate exposure is very important for the removal of a protruded intervertebral disc. This is accomplished by retracting the dura mater or the nerve root in the involved space. The author has used several types of retractors, but the one which proved most satisfactory is described herewith.

The retractor was made from a Simpson uterine sound, the rounded tip end of which was flattened thin (Fig. 1). The handle of the retractor is long and flat, thus preventing rotation. The shaft is made of soft metal which allows it to be bent in any shape for

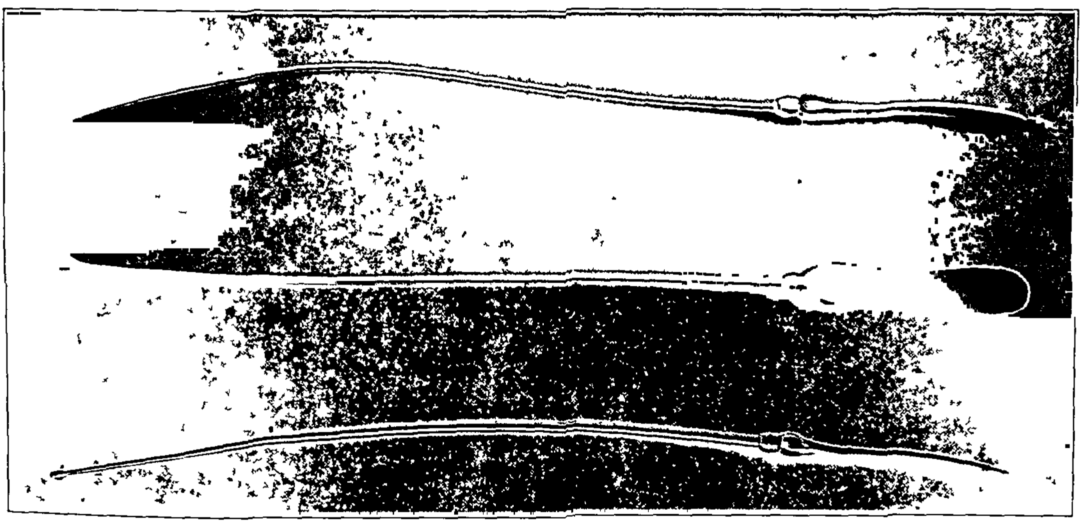

Fig 1

A view of one retractor with a flattened tip after four years' use The other two have not yet had their tips flattened, but show how the retractor may be bent,—convex below, and bayonet-type bend above.

retraction in different types of backs. The bayonet-type bend has been found to be most suitable.

The assistant holds the retractor in his left hand and a sucker in his right, using both sucker tip and retractor tip as blunt dissectors and retractors until the disc is exposed. Exposure is easily maintained with one hand, while the operator removes the protruded disc material. The assistant in no way interferes with the operator, because of the long shaft and handle of the retractor.

Program will be presented under the chairmanship of Dr. Charles N. Pease. At seven o'clock Saturday evening the Instructional Course Dinner will be given, at which President Thomson will read a paper on "Orthopaedic Surgery behind the Iron Curtain". Sir Reginald Watson-Jones will present a paper on "Personal Experiences as Consultant for the Royal Army Air Force".

The Audio-Visual Education Program will continue on Sunday morning from nine o'clock until noon. The Instructional Courses begin at two o'clock Sunday afternoon and run until noon on Monday. The following Courses will be offered:

COURSE I. BONE TUMORS

Introduction	Dr. Henry W. Meyerding
The Pathologic Aspects	Dr. D. B. Phemister, Dr. Mary Sherman
X-Ray Diagnosis	Dr. Edward L. Jenkinson
Clinical Diagnosis and Operative Treatment	Dr. Henry W. Meyerding

COURSE II. WRIST AND HAND

Wrist and Hand	Dr. Sterling Bunnell

COURSE III. PHYSIOLOGY OF BONE

Nutrition, Mineral Metabolism, and Vitamins in Relation to Bone	Dr. F. C. McLean
The Endocrines and Bone	Dr. Edward C. Reifenstein, Jr.
Calcification and Decalcification of Bone	Dr. W. D. Armstrong

COURSE IV. POLIOMYELITIS

Diagnosis and Early Care of Poliomyelitis	Dr. James L. Wilson
Conservative Treatment of Poliomyelitis	Dr. Edward L. Compere
Operative Treatment of Poliomyelitis	Dr. William T. Green

COURSE V. NECK LESIONS

natomy and Physiology of the Neck	Dr. K. B. Corbin
ifferential Diagnosis	Dr. Ralph K. Ghormley
njuries of the Cervical Spine	Dr. Arthur Davis
on-Traumatic Lesions of the Neck	Dr. Carl Badgley

COURSE VI. LOW-BACK LESIONS

natomical Considerations	Dr. Halford Hallock
oentgenography	Dr. Albert Ferguson
ow-Back Syndrome	Dr. Paul Williams
perative Treatment	Dr. Halford Hallock

COURSE VII. CONGENITAL DISLOCATION OF THE HIP

ongenital Dislocation of the Hip	Dr. Joseph Freiberg
arly Management of Congenital Dislocation of the Hip, from Infancy to 8 Years of Age	Dr. H. R. McCarroll
Management of Congenital Dislocation of the Hip in Older Children	Dr. Bruce Gill

COURSE VIII. THE ELBOW JOINT

Orthopaedic Anatomy	Dr. Harold Boyd
Differential Diagnosis and Treatment of Elbow Lesions	Dr. T. L. Waring
Traumatic Lesions About the Elbow	Sir Reginald Watson-Jones

COURSE IX. THE SHOULDER

Orthopaedic Anatomy of the Shoulder	Dr. John Fahey
Differential Diagnosis and Treatment of Common Lesions of the Shoulder	Dr. David M. Bosworth

COURSE X. CEREBRAL PALSY

Conservative Treatment of Cerebral Palsy	Dr. W. M. Phelps
Operative Treatment of Cerebral Palsy	Dr. Fremont A. Chandler

COURSE XI. ORTHOPAEDIC ANATOMY OF THE THIGH

Orthopaedic Anatomy of the Thigh	Dr. J. E. Milgram

COURSE XII. TREATMENT OF CONGENITAL CLUB FEET

Treatment of Congenital Club Feet	Dr. Hiram Kite

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MODIFICATION OF CAST SPREADER

BY FRED A. POLESKY, M.D., LOS ANGELES, CALIFORNIA

From the Department of Orthopaedic Surgery, College of Medical Evangelists and Cedars of Lebanon Hospital, Los Angeles

The cast spreader designed by the author is a modification of some of the cast spreaders which have been in use for many years. One advantage is that the spread of the cast is four and three-eighth inches (Fig. 1-A), which is a greater spread than can be obtained with most instruments now in use. In addition, the handles are so designed that, when the

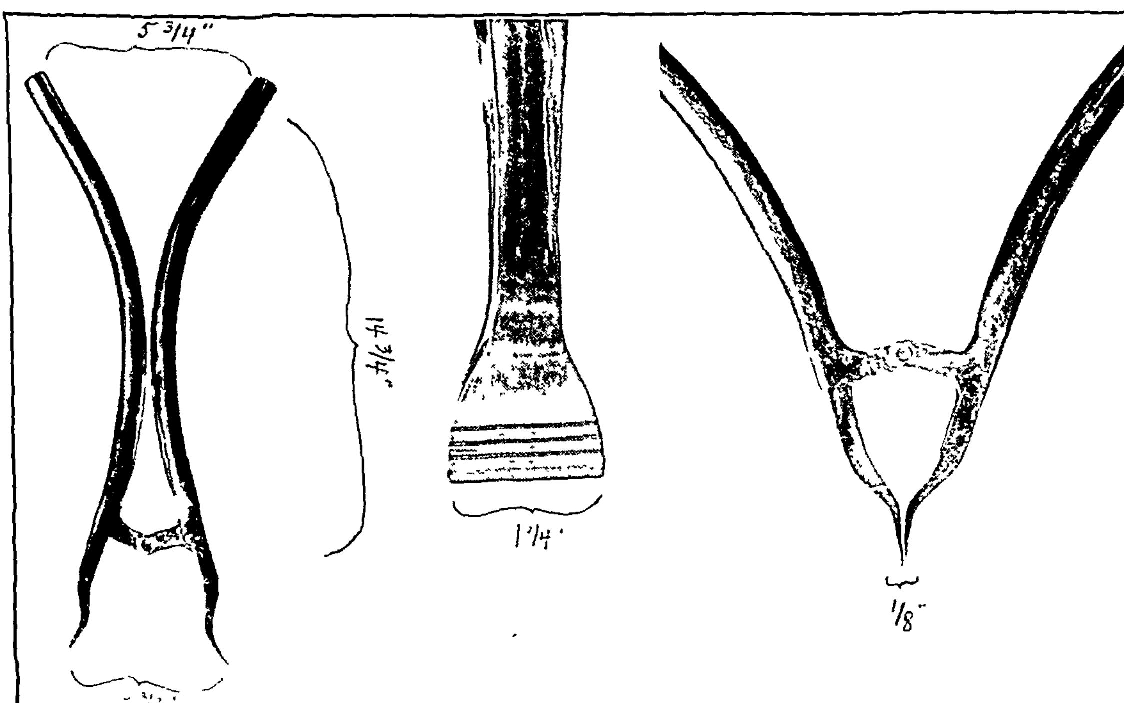

FIG. 1-A FIG. 1-B FIG. 1-C

cast is spread to the maximum, the handles do not come together. This means that the hands of the operator are not bruised at any time.

Another advantage is the length of the spreader, which is fourteen and three-quarters inches. This allows for a greater leverage, and consequently less effort is used in spreading a cast. The serrations on the outer side of the blade are necessary to prevent slipping of the instrument from the cast crevice after the cast has been split.

The cast spreader is made of light metal, and has been found very useful.

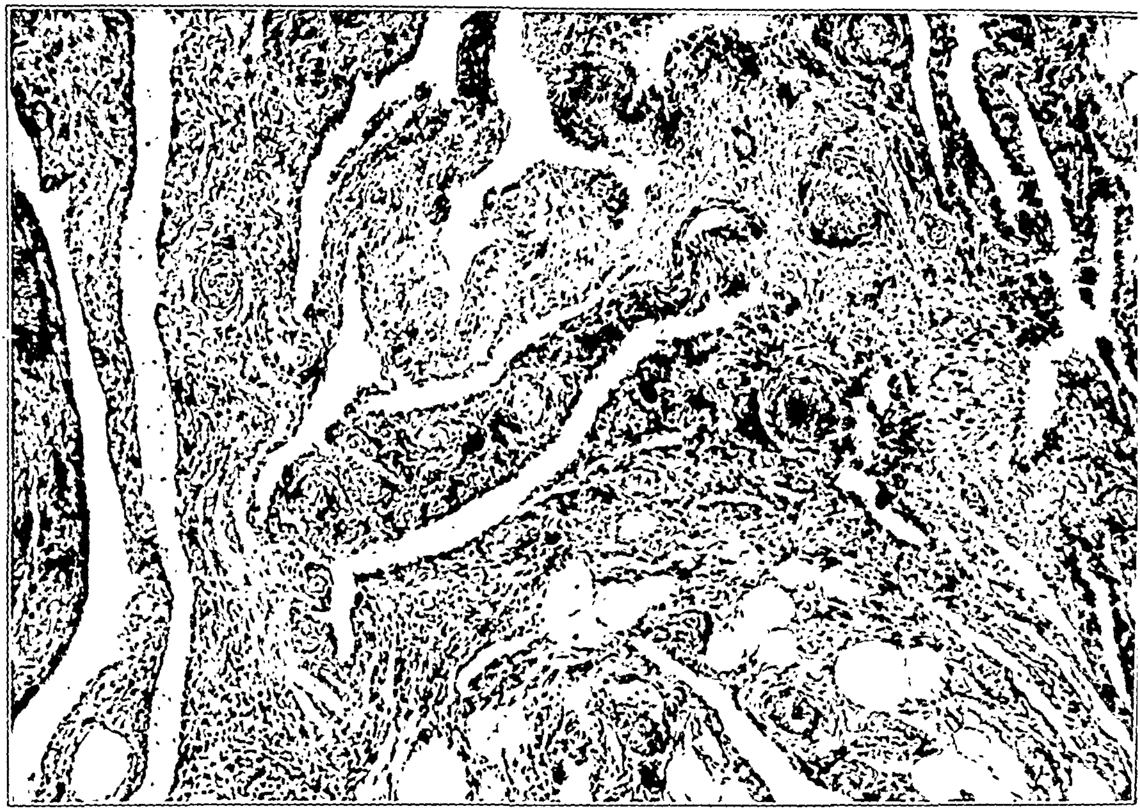

Fig. 1

Photomicrograph (× 100) showing hypertrophied and hemosiderin-laden synovial tissues. This soldier, twenty-four years old, had complained of locking, swelling, and pain in the knee joint. No neoplastic changes were observed, but numerous separate and intercommunicating spaces, lined by synovial cells, were present. Diagnosis: chronic villous synovitis. (A.I.P. Acc. No. 82187.)

The outstanding partisan of "mechanico-therapy" as the distinctive feature of the specialty was Newton M. Shaffer, who was a direct and consistent product of his early environment. He had served as a student assistant of Knight's in his primitive hospital; and, soon after his graduation in medicine, he had joined Taylor at the Orthopaedic Dispensary.

Knight's system of surgicomechanics included every disability amenable to relief by bandaging and bracing.

Taylor's range was by comparison far more limited. In later life, he stated that he had never written a prescription nor attempted a surgical operation, and that his formal medical education was completed in a single year. His original interest was in physical culture. For a time he conducted a gymnasium and devised many machines for automatic exercise. An unfortunate experience in the treatment of Pott's disease led to the invention of the "spinal assistant". Its conception was so novel and startling that, as he told it: "I jumped as if I had received a physical blow, and ran all the way home". By this inspired illumination, as it seemed to him, he became a convert to "mechanico-therapy" and eventually its leading exponent.

Shaffer, his disciple and successor at the New York Orthopaedic Hospital, claimed that its range had never been properly exploited, and that a rich reward awaited those who like himself were content to pursue these "underground but productive investigations". From this standpoint, the combination with operative surgery was impracticable, because one with this radical and superficially effective means at his command would be deflected from the prolonged, difficult, but far more adequate treatment by mechanico-therapy.

Shaffer was an energetic propagandist and, as such, he was particularly concerned with the recognition of the specialty, of which he was the sponsor, as on a par with those already established. He was a leader in the organization of The American Orthopaedic Association and in securing its admission to The Congress of American Physicians and Surgeons in 1888. On this occasion, he was its President and was elected as its delegate to the Council of the Congress. He was also chiefly responsible for the allotment of a special section to Orthopaedic Surgery at the International Congress held at Vienna in 1890.

At this Congress he presented his definition of the scope of the specialty which he represented,—namely, that it should be restricted to the class of cases for which especially designed mechanical appliances were required in treatment. Within these limits, operative intervention might be utilized in a subsidiary capacity, a concession of which he did not avail himself, and for which the Hospital under his control made no provision,—"For in true Orthopaedic Surgery, operative work *per se* has no real status".

Shaffer, as a Professor of Orthopaedic Surgery in a leading medical school and as surgeon-in-charge of the New York Orthopaedic Hospital, spoke as one in authority. As such, he exercised an arbitrary control of his assistants, permitting no divergence from his teaching and practice. Knight, under whom he had served his apprenticeship, had dismissed an able assistant of long standing, because in a publication on hip disease he had endorsed the traction treatment, "which weakened the vital resistance of the limb".

Shaffer, on the contrary, claimed that this method had "revolutionized the treatment of bone and joint disease". He was constrained, therefore, to contrive the dismissal of a former associate from his post at St. Luke's Hospital, because in a ward established by Taylor he had applied Thomas braces in the treatment of hip disease. This arbitrary extension of his authority brought to light the latent opposition to his personality and propaganda and, at the next meeting of The Association, he was displaced as its delegate to the Council of the Congress.

This episode has been considered at length, because the formal rejection of the limitations of scope and method, which Shaffer would have imposed, cleared the ground for a sustained advance, on which its establishment as a restricted specialty served only as a way station.

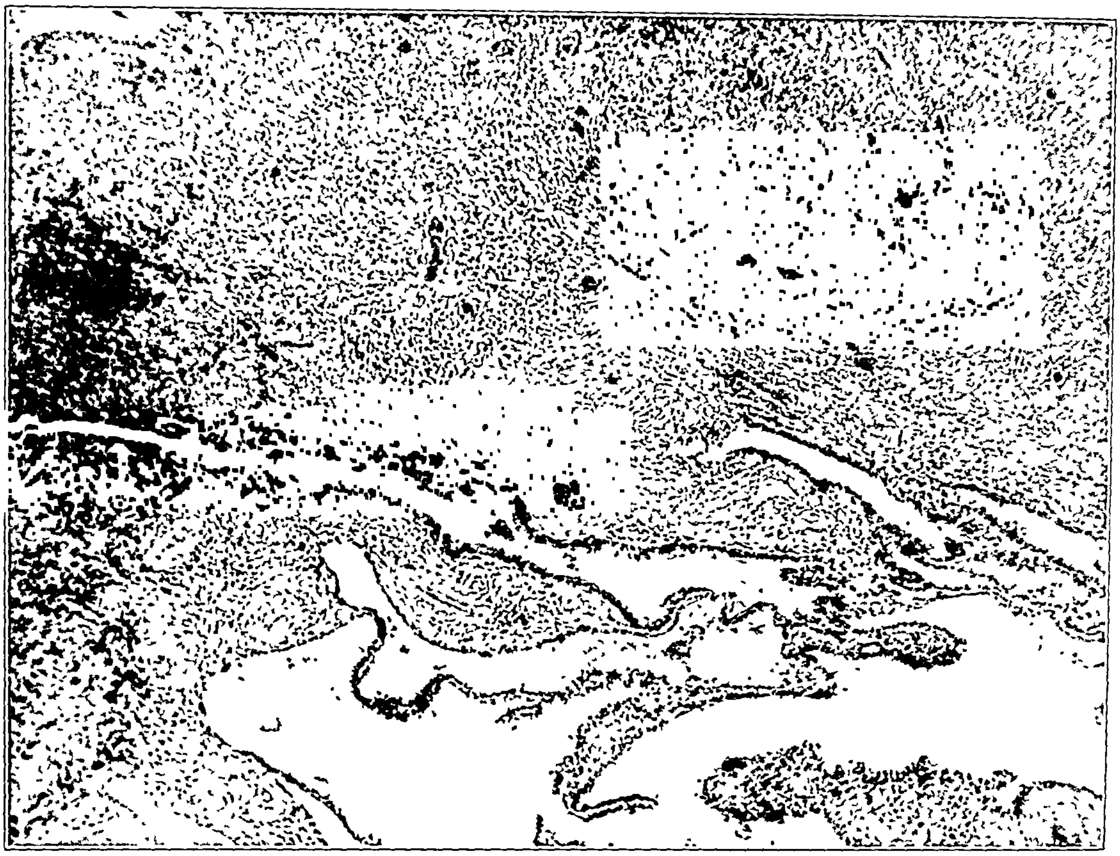

Fig. 5

Photomicrograph (× 55). Reproduction of an area in a firm, but partially cystic, tumor mass, originating in the articular capsule. The sectioned surface was brownish-yellow in color. (A.I.P. Acc. No. 96008.)

Fig. 6

Photomicrograph (× 425) of lesion illustrated in Fig. 5. The similarity of this giant-cell tumor to the lesion illustrated in Figs. 2, 3, and 4 is readily apparent.

of surgery. As such, the obsolescent, but indispensable, term "orthopaedic" designates its sphere of action,—namely, that of anatomical mechanics, of the correction of impairment of bodily structure and function from any cause, and of prevention as well as relief and cure.

Although it may be assumed that this conclusion, based on personal experience, is now generally accepted, a first-hand account of the background and the successive phases of this transformation, as epitomized in a hospital service, may be of interest to the present generation of orthopaedic surgeons.

" 'Tis fifty years since" when, as President of The American Orthopaedic Association, I presented conclusions on its scope and standing, which time has confirmed. Thus, as a participant, I have had an unusual opportunity to observe the formative stage of its development, with which this paper is especially concerned. Since the narrative is based upon personal experience, the field of action has been correspondingly restricted.

ENRIQUE H. LAGOMARSINO
1900–1946

News of the death of Enrique H. Lagomarsino on July 27, 1946, has recently been received. Dr. Lagomarsino was born in Buenos Aires, February 24, 1900. He received his medical degree in 1926, at the School of Medicine of the University of Buenos Aires, and then travelled and studied in Europe for several years. As part of his postgraduate work, he was an Assistant at the *Istituto Rizzoli,* in 1932.

Upon his return to Argentina, he became instructor and later Professor of Topographic Anatomy at the *Facultad de Ciencias Médicas de Buenos Aires.* He was also Professor of Orthopaedic and Traumatic Surgery of the School of Medicine of The University of La Plata, and was Chief of the Orthopaedic and Traumatologic Service at the Central Military Hospital.

Dr. Lagomarsino was a member of a number of societies, including The American Academy of Orthopaedic Surgeons, the Sociedad Argentina de Cirugía Ortopédica, the Sociedad Brasileira de Orthopedia e Traumatologia, and the Société Internationale de Chirurgie Orthopédique et de Traumatologie. He also held memberships in other surgical societies, in Bolivia, Chile, Paraguay, and Peru.

Among his several books, the best known are "Tratamiento de las Fracturas del Cuello del Fémur", written in collaboration with Dr. José Valls, and "Fracturas de la Columna vertebral". He made many contributions to Revista de Ortopedia y Traumatología and other surgical journals.

In a short span of forty-six years, Dr. Lagomarsino accomplished much in his chosen profession that will serve as a lasting memorial to him. He will be missed by his many friends and associates.

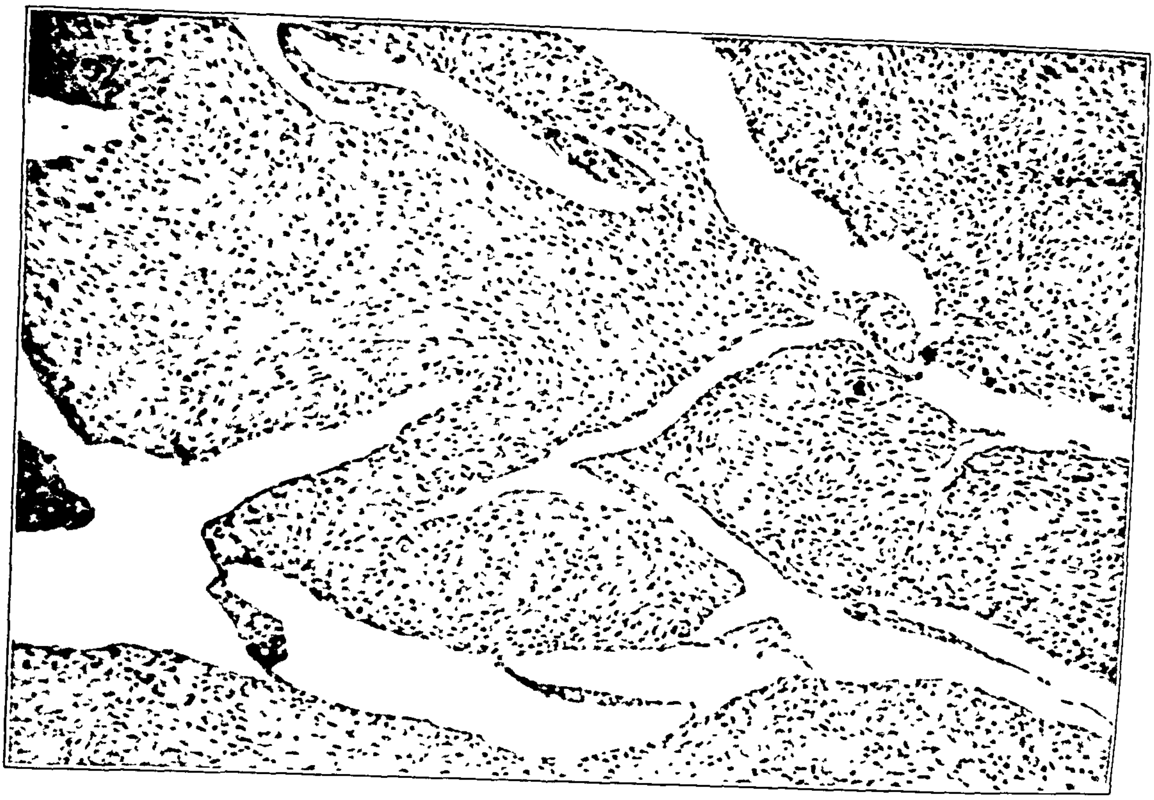

FIG. 10

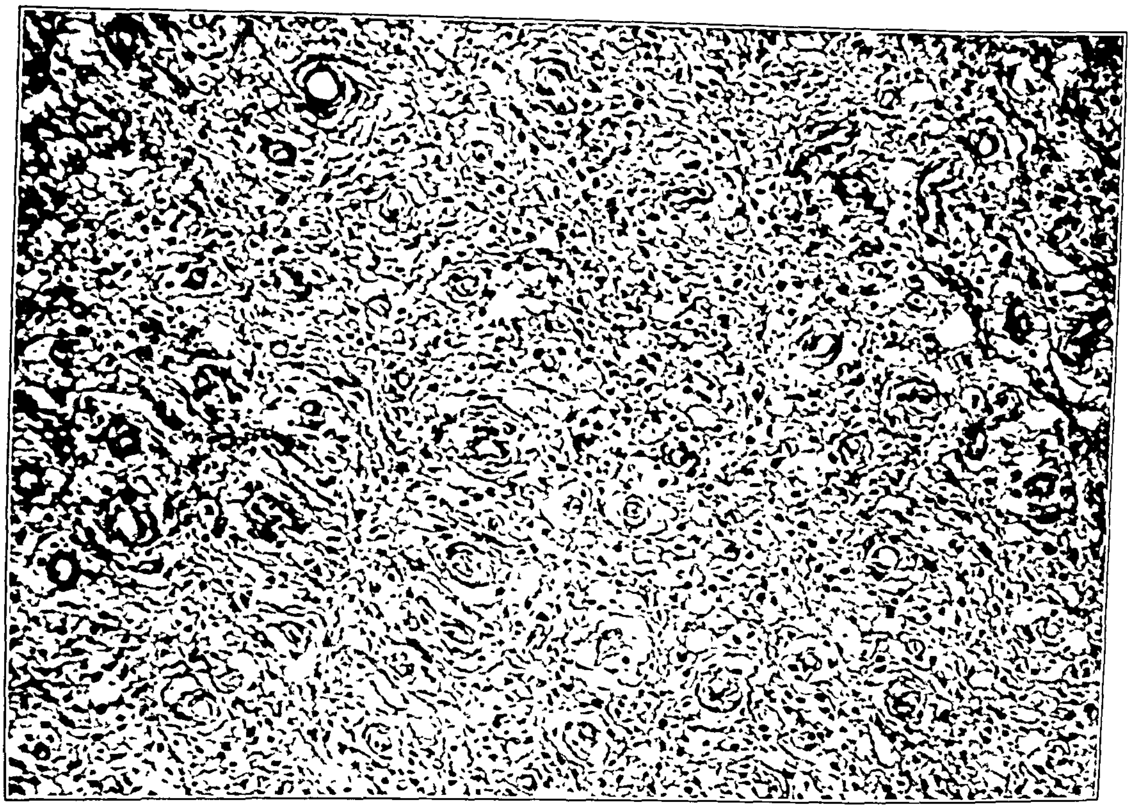

FIG. 11

The pronounced variation in structure and cytological characteristics of the benign neoplasms or tumor-like lesions of synovial tissues is further illustrated. Fig. 10 ($\times$ 50) illustrates the capacity of certain cells to form tissue clefts, while in Fig. 11 the storage of lipoid is clearly shown. The specimen from which these reproductions were made was removed from near the ankle joint of a twenty-one-year-old soldier, who had sustained a crushing injury of the part several years previously. The tumor was encapsulated, spongy in texture, and yellowish-brown in color. Such lesions are frequently referred to as xanthofibromata. However, one can readily demonstrate a close relationship between this example and those illustrated in the previous figures. (A.I.P. Acc. No. 82227.)

fractures involving the subastragaloid (subtalar) joint,—namely, that an incapacity period of about a year in cases treated by reduction and immobilization was approximately halved in cases treated by early movement. More than three-quarters of the patients returned ultimately to full work in their old occupations, and the proportion was not materially influenced by the method of treatment adopted. Mr. W. Gissane, nevertheless, considered reduction important, and showed a film illustrating its performance and maintenance with a sagittal os calcis pin. Mr. K. H. Pridie demonstrated some patients, including a policeman, who showed extremely good function following excision of the os calcis, an operation to be reserved for the most severely affected.

In his presidential address on Rest *versus* Activity in the Treatment of a Fracture, Mr. Perkins confined his remarks to fractures not directly involving joints. In stressing the importance of activity in preserving the extensibility of muscle, and, therefore, preventing stiffness, he pointed out that, if both fragments of a fracture bore muscles, they would afford immobilization, and the sole function of the limited splinting necessary was the preservation of alignment. In other cases (as in fractures of the femoral neck, the medial malleolus, and the scaphoid), splinting was necessary, not merely for alignment but also for immobilization. Such splinting must be prolonged, uninterrupted, rigid, and extensive; consequently, it impaired function, so that internal fixation was often preferable.

Professor E. Sorrel, of Paris, presented a paper on "*Les greffes d'immobilisation dans le traitement des tuberculoses ostco-articulaires*", in which the results of some usual and unusual extra-articular arthrodeses were illustrated. He strongly advocated arthrodesis as a final stage of treatment, to be deferred until active disease was at an end.

Professor H. J. Seddon showed a motion picture of preliminary work, carried out with Dr. A. E. Barclay, in the cineradiography of joint movements.

Mr. K. I. Nissen gave a comprehensive and up-to-date account of Morton's metatarsalgia, with a clinical and pathological description of thirteen cases, followed up for three years or more, in which he had excised the fibromatous thickening (first described by L. O. Betts of Adelaide).

Mr. I. Lawson Dick discussed the later results of iliac-bone transplantation, which were confirmatory of expectations.

Mr. L. Gillis showed a film of his operation for nearthrosis of the humeral shaft in amputations near the elbow joint, which has been described in the *British Medical Journal.*

At a clinical meeting at St. Thomas's Hospital, Dr. J. H. Cyriax presented some observations on dural pain in lumbago and sciatica. Cases were shown of open correction of congenital club-foot (Mr. G. Perkins); osteosynthesis by Küntscher nail (Mr. R. H. Young) and by other methods of internal fixation (Mr. F. A. Simmonds); tendon transplantation for irrecoverable radial (musculospiral) paralysis (Mr. F. C. Durbin); tendon suture (Mr. R. Furlong); and the results of fractures of the tibial plateau (Mr. M. G. Allen) and of crush fractures of the spine (Mr. J. F. Bourdillon).

The Annual Dinner of the Association was honored by the presence of the Prime Minister, the Minister of Health, and the Minister of National Insurance as guests and speakers.

At the General Meeting, Mr. S. A. S. Malkin was elected President for 1948–1949. Professor E. Sorrel, of Paris, was elected an Honorary Fellow; Professor F. E. Godoy-Moreira, of São Paulo, Kamel Bey Hussein, of Cairo, and Dr. Sven Kiaer, of Copenhagen, were made Corresponding Members. Mr. F. G. Allan and Mr. E. A. Nicoll were elected to the Executive Committee.

The following new members were elected:

G. P. Arden, F.R.C.S., Gerrards Cross, Buckinghamshire
Hiren De, F.R.C.S.E., Worcester
H. W. Fitzgerald, F.R.C.S.E., F.R.A.C.S., Dunedin, New Zealand
W. H. Gervis, F.R.C.S., Tunbridge Wells, Kent
Major A. P. Gracie, R.A.M.C., Newton Abbot, Devonshire
K. F. Hulbert, F.R.C.S., London, N 20
A. J. Innes, F.R.C.S., Glasgow, Scotland
T. B. McMurray, F.R.C.S.E., Liverpool
Miss M. G. Murphy, F.R.C.S.E., Harold Wood, Essex
Dr. B. McCall Smith, O.B.E., Glasgow, Scotland
F. G. Ward, F.R.C.S., London, E.C. 1.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Fourteenth Annual Convention of The American Academy of Orthopaedic Surgeons will be held at the Palmer House, Chicago, January 25, 26, 27, 28, 29, and 30, 1947, under the presidency of Dr. J. E. M. Thomson.

Registration will begin at nine o'clock, Saturday morning, January 25. Scientific and Technical Exhibits will be ready for inspection at that time. During the afternoon the Audio-Visual Education

TABLE I (*continued*)

Case No.	A.I.P. Acc. No.	Sex	Race	Age	Status	Location of Lesion	Known Duration Prior to Operation	History of Trauma	Treatment Employed Originally	End Results*
11	100365	Male	White	25	Military	Knee, left popliteal	3½ months	Denied	Biopsy. Disarticulation at hip	Fatal with pulmonary metastases (9 months)
15	93364	Male	White	21	Military	Heel, left	5 months	Denied	Local excision. Amputation below knee 1 month later. Lower-thigh amputation because of infection	Living, no metastases (40 months)
16	89338	Male	White	32	Military	Left foot, dorsum	2 years	Denied	Local excision repeated because of recurrence. Amputation below knee 11 months later	Living; no metastases (20 months). Pulmonary metastases 16 months later
17	115941	Male	White	20	Military	Tibia, upper and medial	2 months	Denied	Local excision	Living, no metastases (24 months)
18	119073	Male	White	23	Military	Groin, right	14 months	Denied	Local excision, followed 2 weeks later by wide excision including lymph nodes	Living; no metastases (22 months)
19	120479	Male	White	19	Civilian	Hand, dorsum, left	?	Denied	Unknown. Specimen was biopsy of a recurrent tumor	Recurred locally; end result unknown
20	125813	Male	White	30	Military	Ankle, left	21 months	Definite	Biopsy. Amputation 2 months later	Fatal with metastases (8 months)
21	114459	Male	White	29	Military	Thigh, right, anterior	2 months	Denied	Local excision	Living; no metastases (16 months)
22	113335	Male	White	47	Civilian	Knee, outer side	3 years	Definite	Local excision. Amputation because of local recurrence	Living; no metastases (25 months)

* Results up to September 1946. Living patients are being followed. Months specified are from time of operation until last report.

COURSE XIII. X-RAY DIAGNOSIS OF THE EXTREMITIES AND SPINE

X-Ray Diagnosis of the Extremities	Dr. Albert B. Ferguson
X-Ray Diagnosis of the Spine	Dr. Albert B. Ferguson

On Monday afternoon, Tuesday, Wednesday, and Thursday morning, the Scientific Program will be given, and Academy luncheons will be held at one o'clock on each of these days.

There will be Executive Sessions at noon on Tuesday and at noon on Thursday for members only.

The following program has been selected by the Program Committee under the chairmanship of Dr. Harold B. Boyd:

MONDAY, JANUARY 27

Afternoon Session

Treatment of Ununited Fractures by Onlay Grafts Without Screw or Tie Fixation.
Dallas B. Phemister, M.D.

Bone Grafts, an End-Result Study of the Healing Time.
W. A. Bishop, Jr., M.D.
Richard C. Stauffer, M.D.
Capt. Alvin L. Swenson, M.C.

A Method Combining a Bone Graft and Metal Plate in Non-Union of Long Bones.
G. Mosser Taylor, M.D.

Some Unusual Clinical and Pathological Aspects of Trauma.
C. Fred Ferciot, M.D.
Frank H. Tanner, M.D.

Preliminary Report from the Committee on Artificial Limbs.
Rufus H. Alldredge, M.D.

TUESDAY, JANUARY 28

Morning Session

Slipping Epiphysis in the Adolescent Hip.
Paul H. Martin, M.D.

Malunited Displaced Upper Femoral Epiphysis. End-Result Study of Sixty-Five Cases Treated by Osteotomy of Surgical Neck with Internal Fixation.
Carl E. Badgley, M.D.
John Wolgamot, M.D.
James Miller, M.D.

Treatment of Congenital Dislocation of the Hip.
Professor Mudr. Bedřich Frejka, Brno, Czechoslovakia

Intertrochanteric Fractures of the Femur; A Survey of Treatment by Traction and Internal Fixation.
Mather Cleveland, M.D.
David M. Bosworth, M.D.
Frederick R. Thompson, M.D.

Principles of Treatment of Multiple Limb Injuries.
Sir Reginald Watson-Jones, London, England

Afternoon Session

Results of Recent Studies and Experiments Concerning Internal Fixation of Fractures with Metals.
Charles S. Venable, M.D.
Walter D. Stuck, M.D.

The Iliac Apophysis: An Invaluable Sign in the Management of Scoliosis.
Joseph C. Risser, M.D.

Anterior Tibial Tendon Transposition in Recurrent Congenital Club-Foot.
George J. Garceau, M.D.
K. R. Manning, M.D.

Arthroplasty of the Hip for Congenital Dislocation in Children.
Paul C. Colonna, M.D.

Coxa Plana.
M. B. Howorth, M.D.

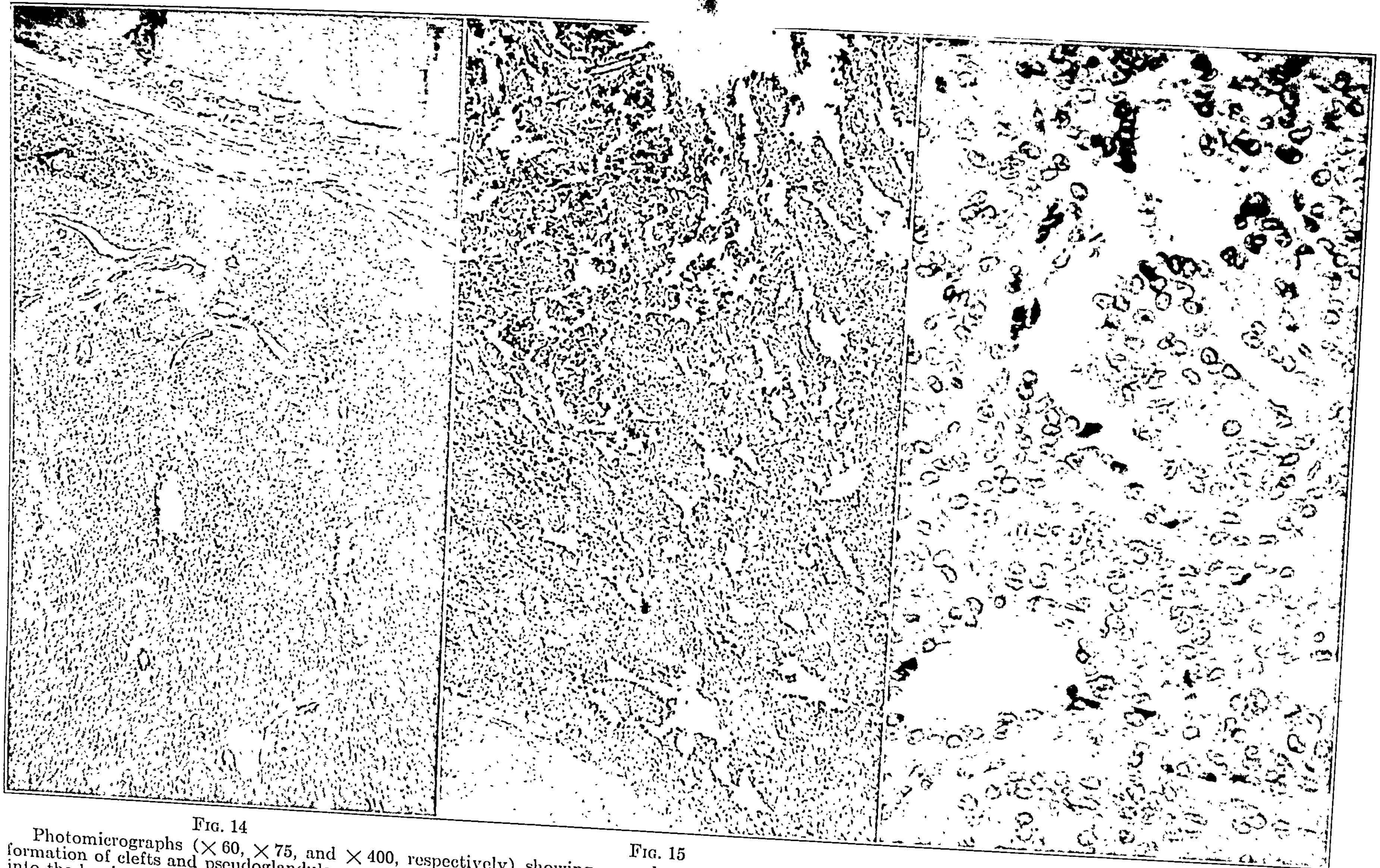

Fig. 14 Fig. 15 Fig. 16

Photomicrographs (×60, ×75, and ×400, respectively) showing a moderately cellular invasive tumor, in which the outstanding characteristic is the formation of clefts and pseudoglandular spaces that are lined by flattened and low cuboidal cells. Small tufts of such cells form small papillary projections into the lumina of the spaces. The resemblance of this lesion to certain benign overgrowths of synovial tissues (Figs. 2, 3, and 4) is apparent. Such similarities are responsible for the difficulties that are frequently encountered in microscopic diagnosis, and point to the need for careful follow-up studies in the group of synovial tumors that are believed to be benign.

This specimen (Case 3) (A.I.P. Acc. No. 117723) was an egg-shaped mass of soft semicystic tissue, which extended somewhat into the tibial cortex medial to the tibial tubercle.

or in military hospitals. The thigh (five cases) and the region of the knee (eight cases) were the sites where the tumors most commonly occurred. Most of the tumors seemed to arise in either the popliteal space or in Hunter's canal. Four tumors arose from the soft

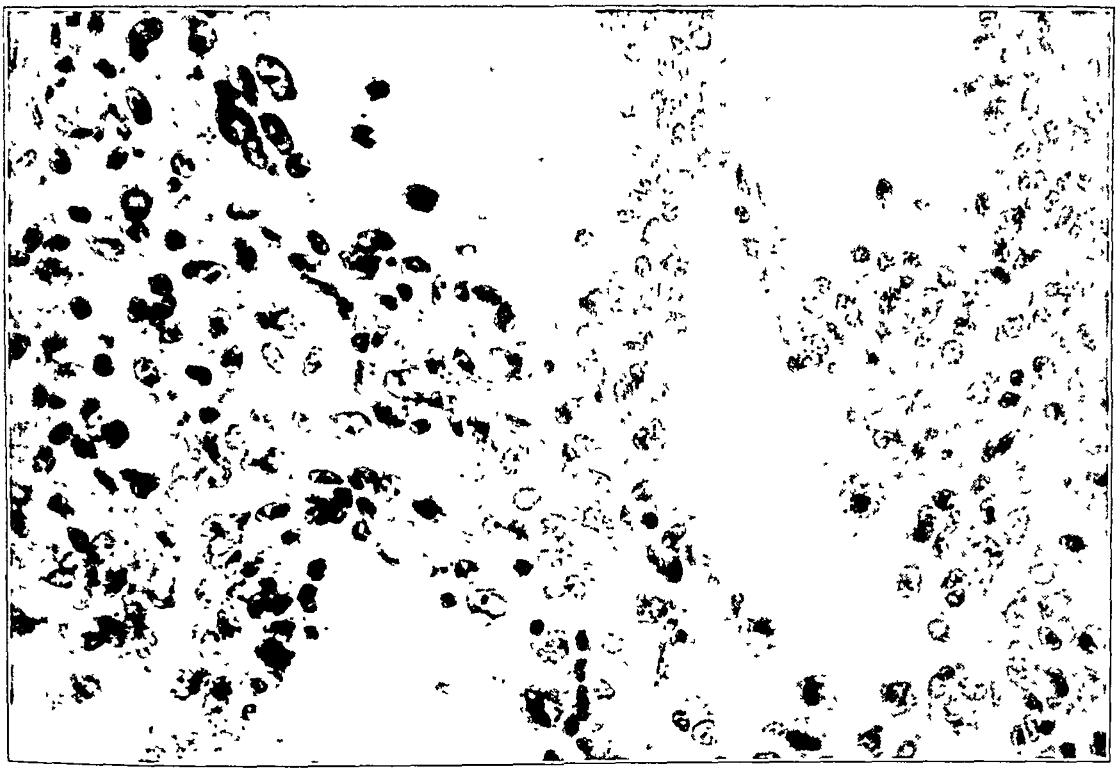

FIG. 3
Photomicrograph (× 425) of a cystic portion of the lesion illustrated in Fig. 2.

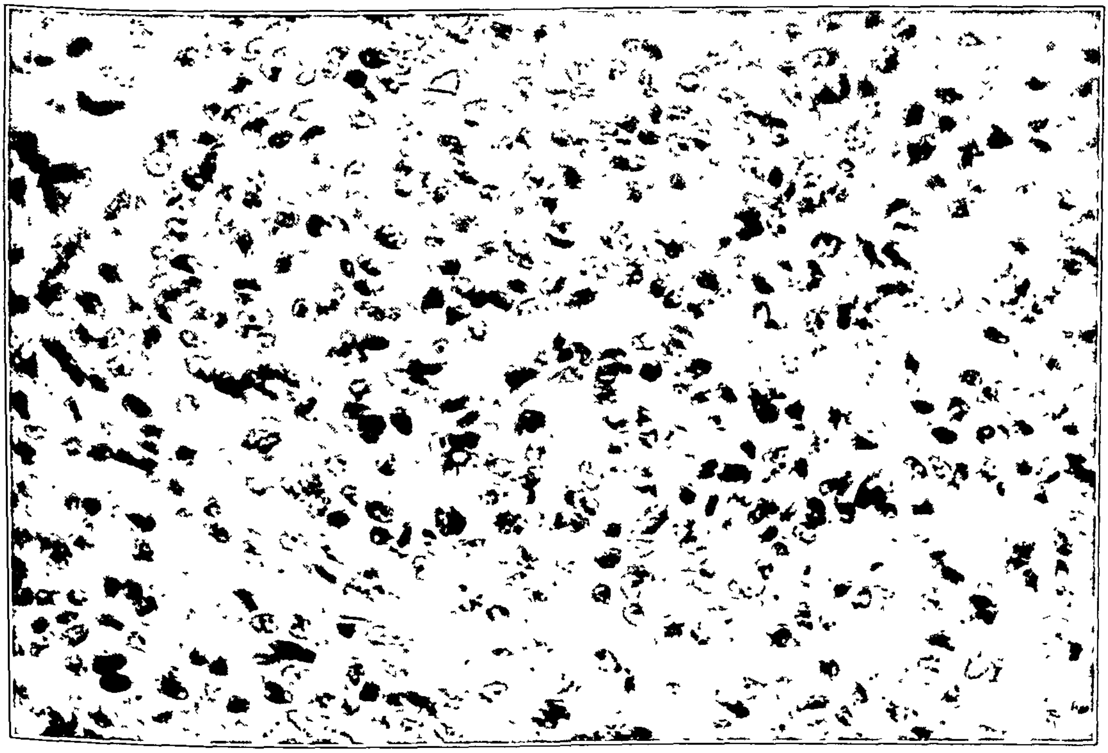

FIG. 4
The cellularity of one of the solid portions of the synovial-membrane lesion shown in Figs. 2 and 3 is illustrated in this photomicrograph (× 425). (A.I.P. Acc. No. 90791.) Other areas in this specimen contained giant cells and lipoid-laden phagocytes, similar to those illustrated in Figs. 7 through 13.

fibrous connective-tissue elements would form the most conspicuous component of the neoplasm. In other new growths, tufting or villous patterns of growth would prevail. In still other examples, the capacity of the neoplastic cells to line spaces, with or without evidencing their secretory propensity, would determine the character of the lesion.

The widespread distribution of synovial tissues in the body and their possible development from other mesenchymal tissues, when appropriately stimulated, undoubtedly explains the occurrence of synovial-membrane tumors in the areas which are well removed from the articulations themselves.

TUMOR-LIKE HYPERPLASIAS AND BENIGN NEOPLASMS

The need for establishing, if possible, criteria by which benign lesions arising from synovial tissues may be differentiated sharply from those that are likely to recur and metastasize, has become increasingly apparent in reviewing this series of cases.

Benign lesions, similar to those illustrated in Figures 1 through 11, but embracing the widest range of variations, constituted a large block of pathological material in the various laboratories of the military hospitals. This striking incidence may have resulted in part from the rigorous physical demands that were placed upon the military personnel. Attention was no doubt directed to many symptomless lesions by these increased physical demands. It is well known, however, that such lesions are common among the civilian population. The history of pain (Case 3) or swelling (Cases 4, 5, 8, 9, 12, 16, 22, and 32) for many months to several years prior to the onset of a rapidly growing neoplasm suggests that, in some instances, malignant tumors of synovial tissues may be preceded by benign tumors or perhaps even by non-neoplastic reactive proliferations. DeSanto and Wilson found no instance in which a "benign giant-cell xanthoma" had undergone malignant transformation. On the other hand, Jaffe, Lichtenstein, and Sutro caution against the possible recurrence of the lesion they designate as "villonodular synovitis" unless it is completely excised. They point out that the recurrent lesion is likely to be somewhat more "florid" than the original one.

Numerous blocks of tissue may be required for the proper microscopic interpretation of any given lesion of the synovial tissues. This is well shown in the material from Case 5 (Figs. 19 through 24) and in Case 29 (Figs. 49 through 54). In these and other instances, some blocks of tissue showed only fibrous connective tissue, containing fat deposits, calcareous incrustations, and villous overgrowths of synovium (Figs. 20, 21, 22, and 49), whereas other sample blocks revealed highly cellular neoplastic growths which, in each instance, had metastasized to other organs.

It seems probable that a follow-up study of all cases from which synovial-membrane lesions, now classified as benign or non-neoplastic, have been removed, will be highly informative in the future interpretation and management of such conditions.

MALIGNANT TUMORS DERIVED FROM SYNOVIAL TISSUES

In 1927, Smith reviewed the literature pertaining to malignant tumors derived from synovial tissues and suggested the term "synovioma" to designate a lesion of a particular type which he had observed in three patients. Following this report, increasing numbers of tumors of the type described by Smith have been recognized, and numerous series of cases have been recorded.

One report[3] deals with nine cases registered with the Army Medical Museum in the decade prior to the second World War. Certain other authors[2,5,9] have assembled their own and the previously reported cases in tabular form for analysis. More recently, Haagensen and Stout reviewed the cases in the literature and found ninety-five acceptable examples of synovial sarcoma which, with nine additional ones from their own material, formed a total of 104 cases for analysis. Only three of these patients were alive and free of metastases five years after treatment had been instituted.

FIG. 7

A low-power (× 55) photomicrograph of a representative area in a slowly growing tumor nodule, removed from the tissues adjacent to the terminal phalanx of the left great toe. The tendon-sheath origin of this neoplasm is clearly evident. (A.I.P. Acc. No. 83213.)

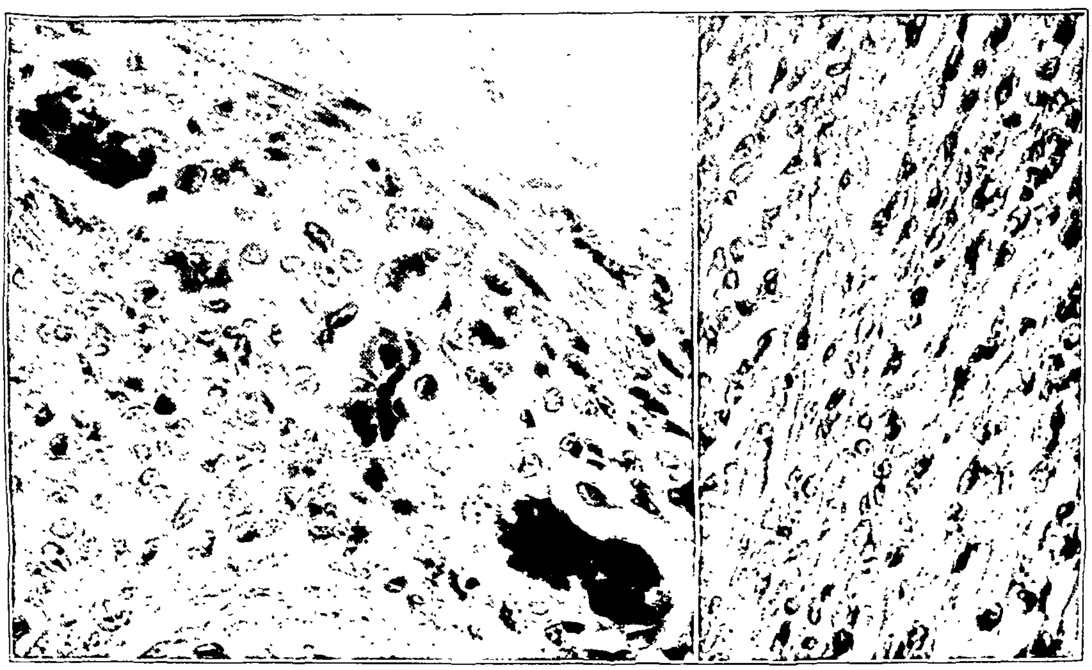

FIG. 8 FIG. 9

Contrasting areas from the tumor illustrated in Fig. 7, showing giant-cell components and moderately cellular fibrous areas (× 400). The similarity of this neoplasm to the lesion illustrated in Figs. 2, 3, and 4 is readily apparent. Diagnosis: benign giant-cell tumor of tendon-sheath origin.

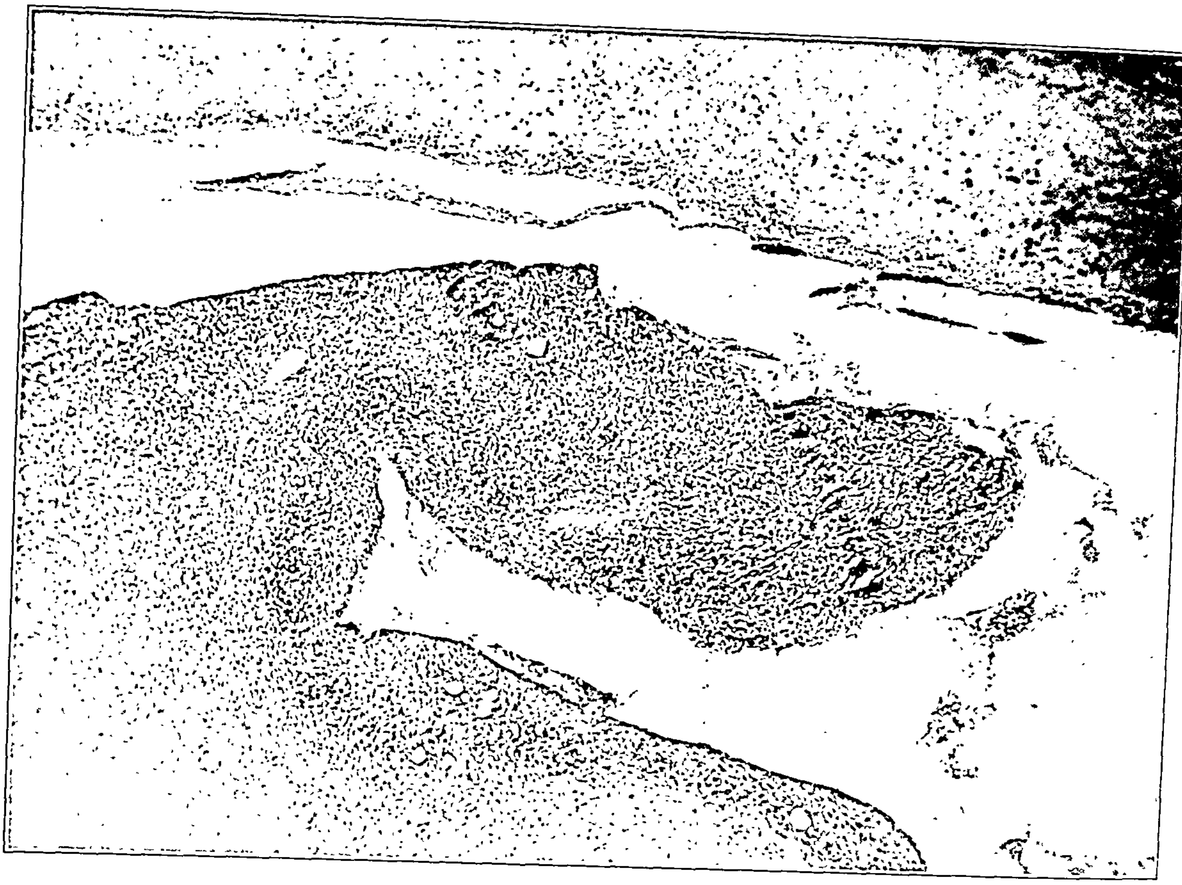

FIG. 21
Tumor tissue forming the lining of the fibrous wall of the cystic tumor is shown in this photomicrograph (× 55).

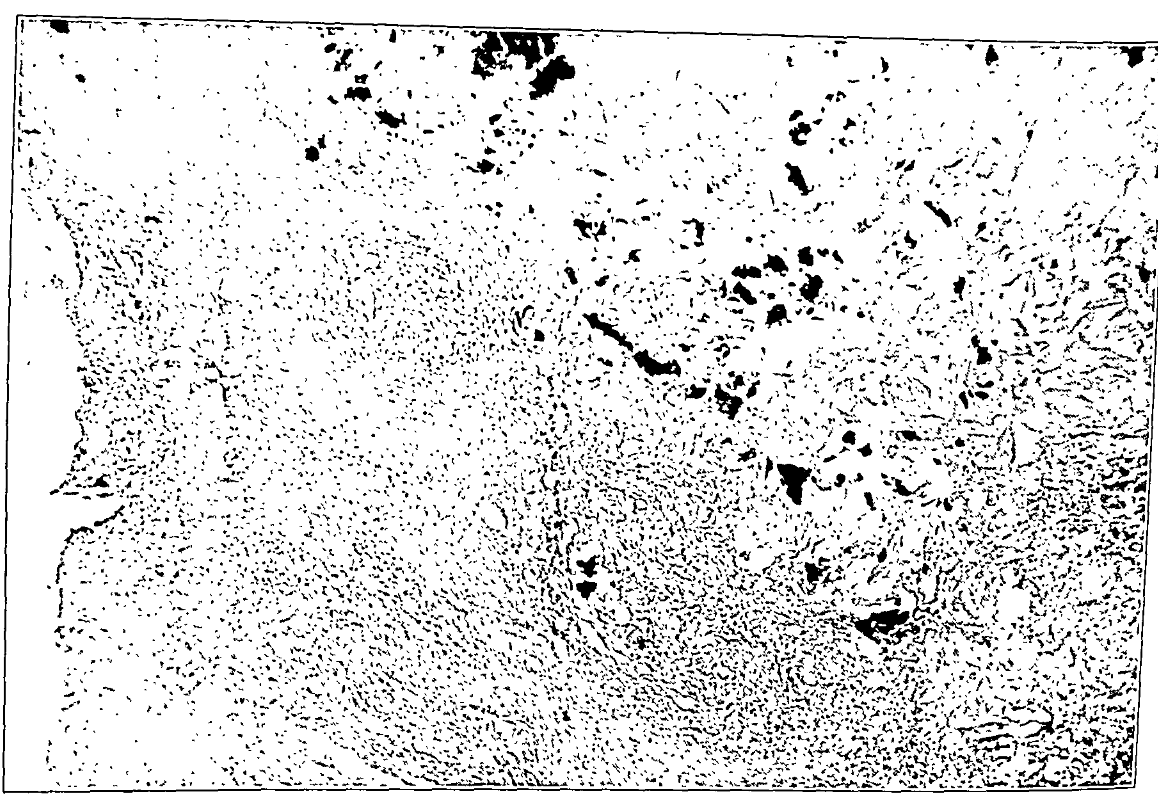

FIG. 22
Areas of degeneration, fat deposition, and calcification are illustrated in this photomicrograph (× 55). Such regressive changes are frequently observed in sarcomatous tumors derived from synovial tissues. Figs. 21 and 22 are from the tumor shown in Fig. 19.

TABLE I
CLINICAL DATA

Case No.	A.I.P. Acc. No.	Sex	Race	Age	Status	Location of Lesion	Known Duration Prior to Operation	History of Trauma	Treatment Employed Originally	End Results*
1	108027	Male	White	22	Military	Thigh, left	6 months	Denied	Local excision	Living; no metastases
2	117907	Male	White	25	Military	Thigh, left anterior	5 months	Definite	Local excision	Living; metastases to lungs (23 months)
3	117723	Male	White	20	Military	Tibia, tubercle	Pain, 3 years Tumor, 5 months	Questionable	Local excision, including bone curettement	Unknown
4	111129	Male	White	21	Military	Ankle, left	Painless swelling, 6 years	Denied	Local excision	Unknown
5	94431	Male	Negro	30	Military	Knee, left	4 years; growing 1 year	Questionable Left knee injured 10 years earlier	No local treatment, due to metastasis	Fatal with pulmonary metastases (1 month)
6	80133	Male	White	35	Military	Knee, left patellar tendon	?	Denied	Local excision	Living; no metastases (54 months)
7	81174	Male	?	22	Military	Tendo achillis	7 months	Denied	Local excision	Recurrence; living (53 months)
8	85357	Male	White	21	Military	Tibia, right upper third	2 years	Definite; to tumor	Local excision. Later wide excision because of recurrence	Recurrence, 2 months; living (47 months)
9	92271	Male	?	29	Military	Foot, left plantar	Many years	Definite; to tumor	Local excision	Unknown
10	117091	Male	?	34	Civilian	Knee, popliteal	6 months	Denied	Local excision	Fatal with pulmonary metastases (5 months)
11	85248	Male	White	24	Military	Knee, left, above patella	6 months	Definite, 5 years before	Local excision	Fatal with pulmonary metastases (17 months)
12	128877	Female	White	56	Civilian	Upper arm	2 years	Denied	Local excision	Living; no metastases (18 months)
13**	113906	Male	White	19 days	Civilian	Left leg	Present at birth	Denied	Amputation	Unknown

* Results up to September 1946. Living patients are being followed. Months specified are from time of operation until last report.
** Treated in military hospital.

to the fact that the neoplasm grows expansively from a focal point, the adjacent tissues become compressed and attenuated to form a pseudocapsule. The appearance of encapsulation is frequently striking, and the surgeon may conclude erroneously that local excision by blunt dissection will effectively eradicate the lesion. In the process of removal it is frequently noted that the new growth is more firmly attached to a tendon, tendon sheath, or other adjacent tissues at one or several points. Such areas of anchorage may represent either the point of origin of the tumor or an area of invasion. Differing textures and elastic qualities of the adjacent tissues lead to nodular irregularities in the outline of the neoplasms. Most tumors are seen to be of various densities and colors in cross section. Some are firm in texture and moderately fibrous, but more frequently they are soft, spongy, and friable.

Pinkish-gray areas of viable tumor tissue are frequently interspersed with yellow areas, caused by necrosis, and brown or red portions which have resulted from old or recent hemorrhage. Occasionally calcification in the form of finely divided gritty particles will be noted, or less frequently large plaques of mineral incrustations in one or several portions of the neoplasm.

It is worthy of note that these tumors seldom form within the cavities of the joints; instead they lie in close proximity to tendons, tendon sheaths, and the exterior walls of the bursal pouches or joint capsules. Those that occur in the middle or upper third of the thigh or arm may show no connection with any structure having a recognizable lining of synovial membrane, and for this reason the true nature of the tumor may not be suspected until after the microscopic sections have been examined.

Microscopic Appearance

In order to interpret properly the varied microscopic patterns that may be encountered in tumors derived from synovial tissues, it is necessary to recall that articular cavities are formed from the primitive mesenchymal tissues destined to become the skeleton. Thus the synovial-lining components of the articular spaces not only arise from the same connective tissues from which the other skeletal parts originate, but they merge imperceptibly into the fibrocartilaginous and hyaline-cartilaginous structures, on the one hand, and the dense fibrous capsular tissues of the articular walls, on the other. It must also be remembered that following synovectomy, a new synovial-lining membrane will be formed, frequently indistinguishable from the earlier one. It appears probable, therefore, that the special structural and functional characters of the synovial-lining cells are the result of two main factors: (a) the inherent propensities of the cells to line surfaces and produce mucin, and (b) the environmental circumstances governed to a large extent by the function of the part.

If these assumptions are correct, it is not difficult to comprehend the many patterns that are observed in synoviomata. One would logically expect that neoplasms arising from the articulations would in some instances reproduce undifferentiated connective tissues, while in other instances the more highly specialized propensities of the cells would result in the formation of synovial-membrane patterns or even cartilage. This seems to be the case, beyond any reasonable doubt.

Thus, in the study of neoplasms arising from or near the articular, bursal, or tendinous structures of the body, one encounters tumors that range in architectural pattern and cellular composition from ordinary fibrosarcomata to the highly specialized and equally characteristic synovial sarcomata. It is not easy to establish criteria which will clearly distinguish between these two classes of malignant tumors.

In the present study, no tumor was included as one derived from and reproducing synovial-tissue elements, unless the cytological picture and structural features were reasonably characteristic. An attempt has been made, however, to illustrate the variability of the microscopic picture from the simplified forms (Figs. 14 through 18, and 23 through 29)

TABLE I (*continued*)

Case No	A I P Acc No	Sex	Race	Age	Status	Location of Lesion	Known Duration Prior to Operation	History of Trauma	Treatment Employed Originally	End Results*
23	105488	Male	Negro	30	Military	Knee, left	17 months, growth 1 year	Denied	Biopsy Amputation through lower thigh; dissection of lymph nodes in groin	Unknown
24	138872	Female	White	21	Civilian	Right femur, over trochanter	1 year	Denied	Local excision	Unknown
25	101006	Male	White	24	Military	Thigh, left	13 months	Denied	Local excision	Local recurrence (12 months) Fatal with metastases (22 months)
26	116739	Male	White	32	Military	Elbow, right	6 months	Questionable	Biopsy Local excision 1 month later	Fatal with pulmonary metastases (12 months)
27	128221	Male	White	40	Civilian	Ilium right	6 months	Denied	Biopsy	Fatal with pulmonary metastases (date unknown)
28	115110	Male	White	26	Military	Shoulder, right	1 month	Denied	Exploration and biopsy Shoulder girdle amputated 3 months later	Unknown
29	97736	Male	White	31	Military	Thigh, left	Mass for 4 months	Questionable Varicose veins injected	Biopsy	Fatal with widespread metastases (6 months)
30	123312	Male	White	23	Military	Elbow, right	6 months	Denied	Biopsy of metastases 3 mo after primary tumor was noted X-ray therapy	Fatal with widespread metastases (9 months)
31	117805	Male	White	35	Military	Knee, right	18 months, recent rapid growth	Denied	Synovectomy	Unknown
32	117113	Male	White	21	Military	Ankle, left	6 months, (intermittent pain and swelling for 6 years)	Questionable Injury 6 years before	Biopsy Amputation 1 month later	Fatal with pulmonary metastases (5 months)

* Results up to September 1946 Living patients are being followed Months specified are from time of operation until last report

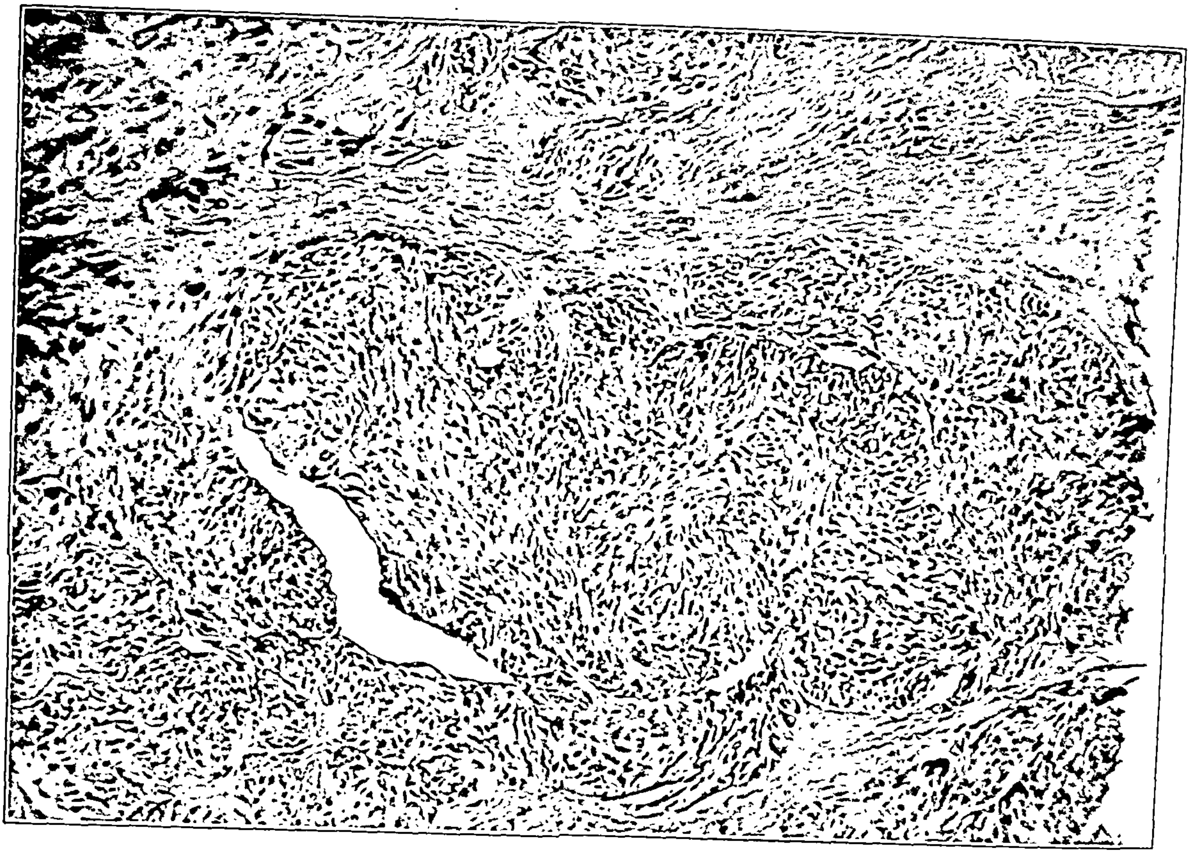

Fig. 28

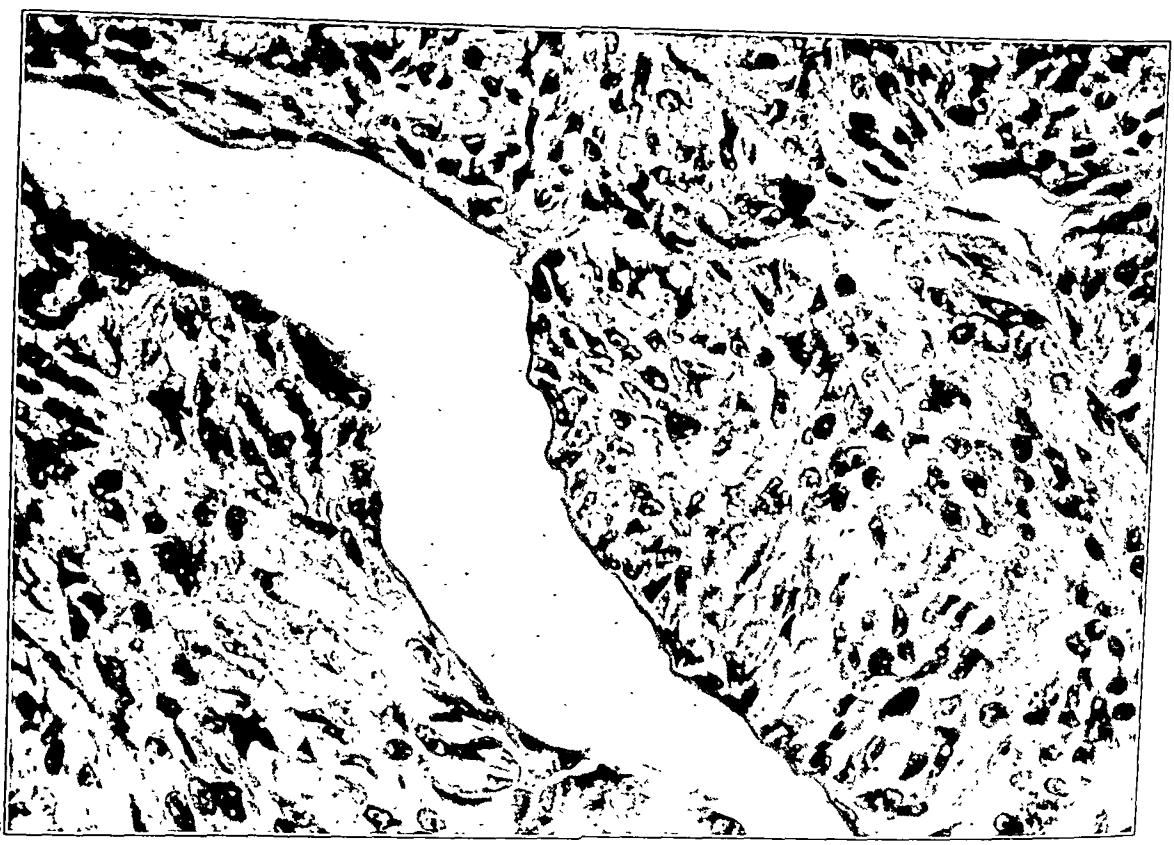

Fig. 29

Figs. 28 (× 128) and 29 (× 450). By comparison with the tumor illustrated in Figs. 25, 26, and 27, this tumor (Case 7) shows a more pronounced clefting. The papillary projections of such cells into preformed spaces is also more distinct. This tumor arose from the tissues close to the insertion of the tendo achillis, but was apparently unattached to the tendon itself. (A.I.P. Acc. No. 81174.) (Cases 8, 9, and 10 were similar in microscopic structure to the illustrated Cases 6 and 7.)

FIG. 17

Case 4. Photomicrograph (× 70) of a partially cystic tumor, growing from the medial aspect of the left ankle joint. A painless swelling had been present for six years. Macroscopically the tissue was soft, friable, and white in color.

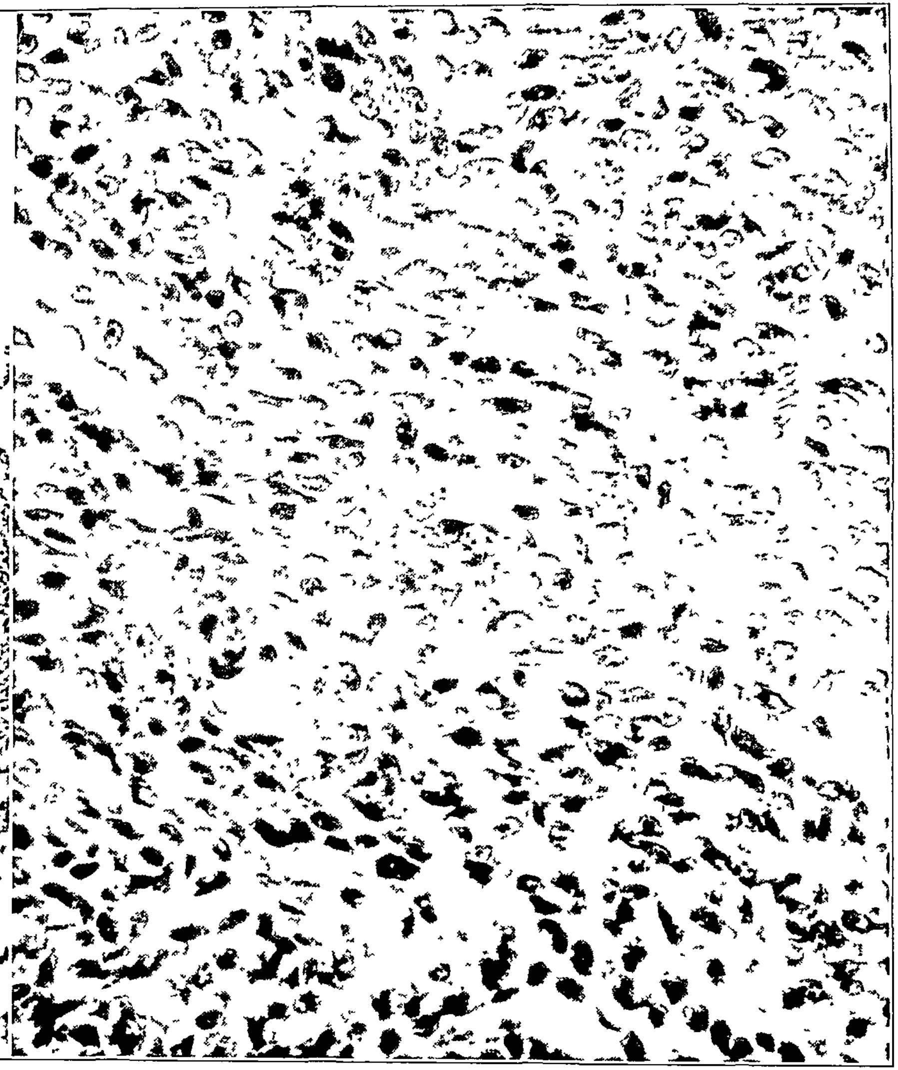

FIG. 18

Photomicrograph (× 550) of the tumor illustrated in Fig. 17. Although the tumor is comprised of relatively undifferentiated small oval and spindle-shaped cells, there is a suggestion of cleft formation in some areas. Such spaces are lined by flattened mesothelial cells. (A.I.P. Acc. No. 111129.)

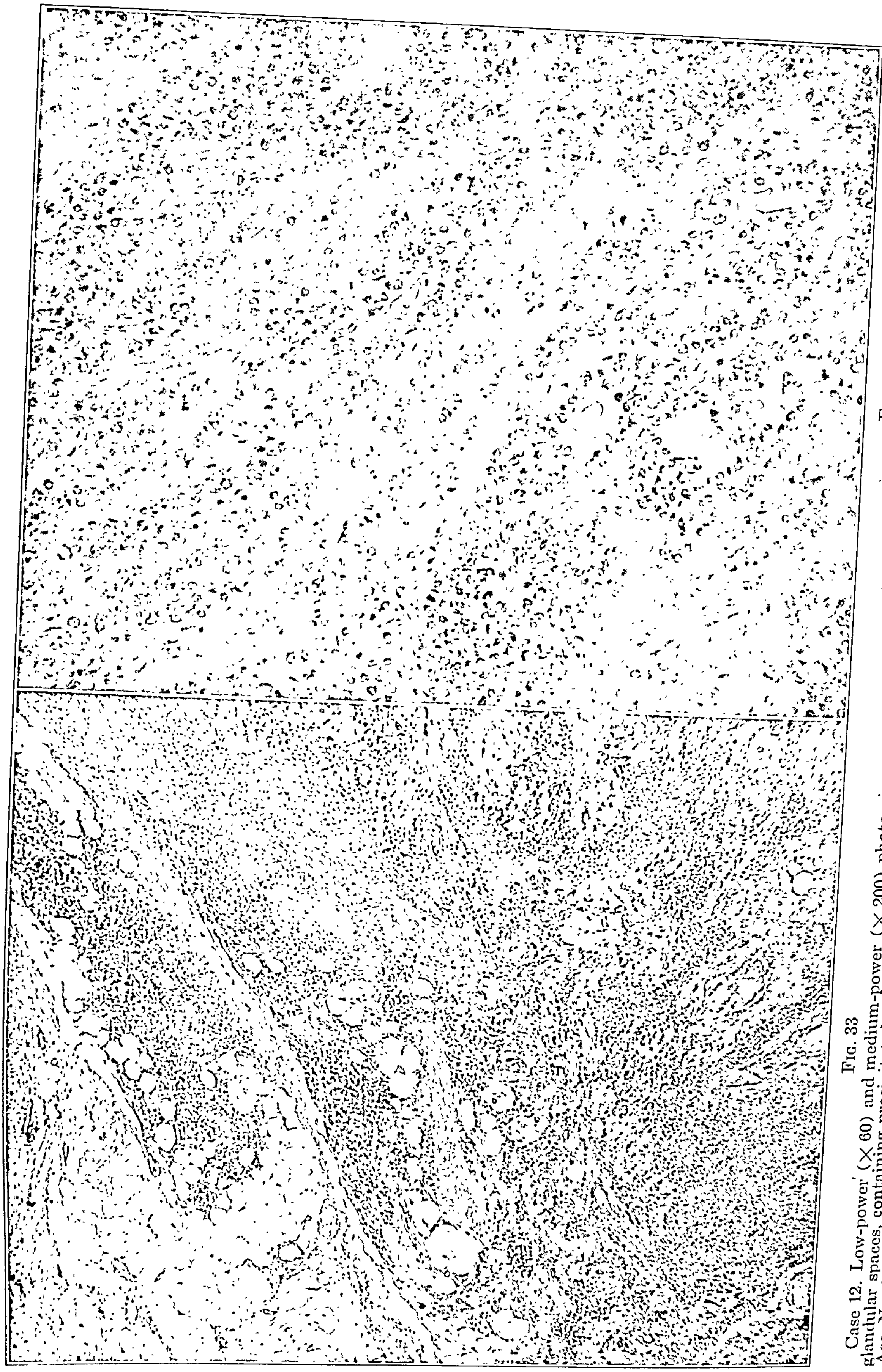

Fig. 33

Fig. 34

Case 12. Low-power (× 60) and medium-power (× 200) photomicrographs of a tumor arising in the upper arm, just anterior to the humerus. Pseudo-glandular spaces, containing precipitated secretion, are unusually prominent in this tumor. Compare with benign lesion shown in Figs. 2 and 3. (A.I.P. Acc. No. 128877.)

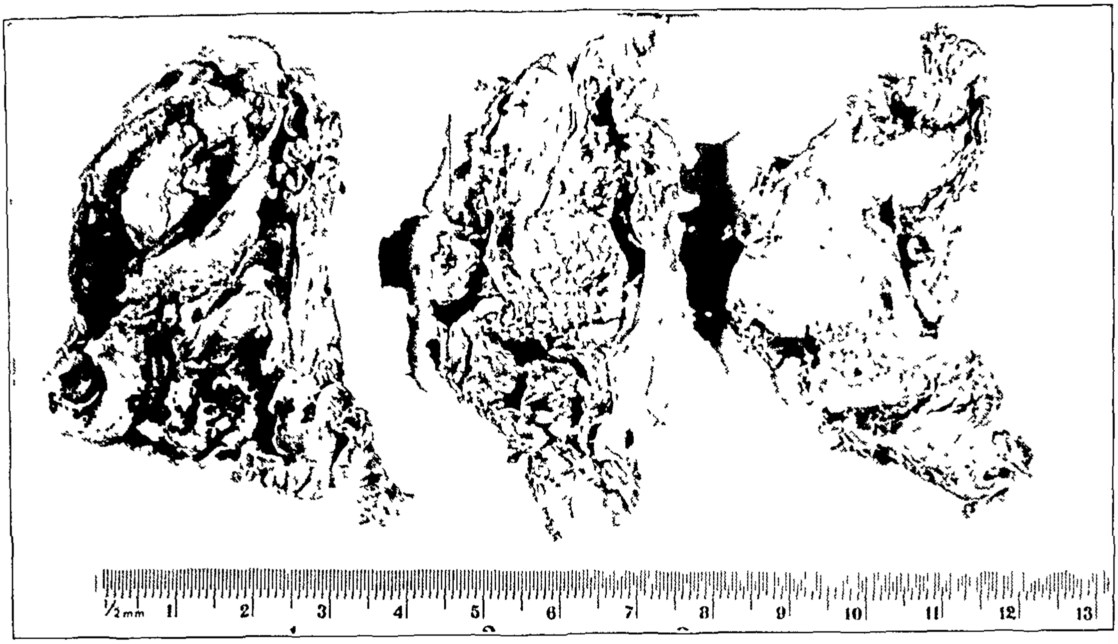

FIG. 19

Case 5. The sectioned surfaces of a soft, partially cystic tumor, arising in the soft tissues just below and medial to the left knee. The malignant qualities of the neoplasm were proved by the subsequent metastases and the fatal outcome. (A.I.P. Acc. No. 94431.)

FIG. 20

Highly cellular areas and intervening fibrous trabeculae are indicated in this photomicrograph (× 55) of the tumor illustrated in Fig. 19.

PATHOLOGY

Macroscopic Appearance

Sarcomata derived from synovial tissues are variable in size, texture, and appearance (Figs. 12, 13, 19, and 35). In the usual example, the tumor is sharply circumscribed. Owing

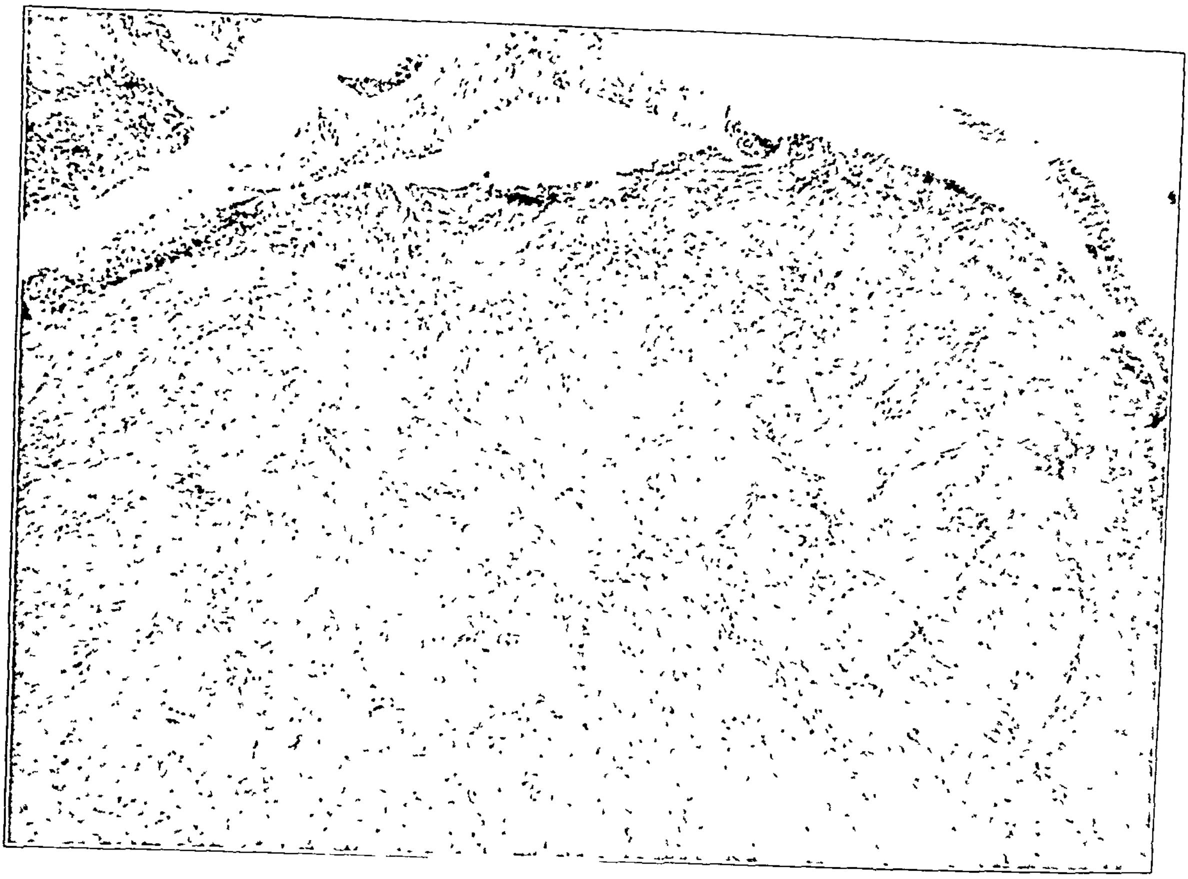

FIG. 38

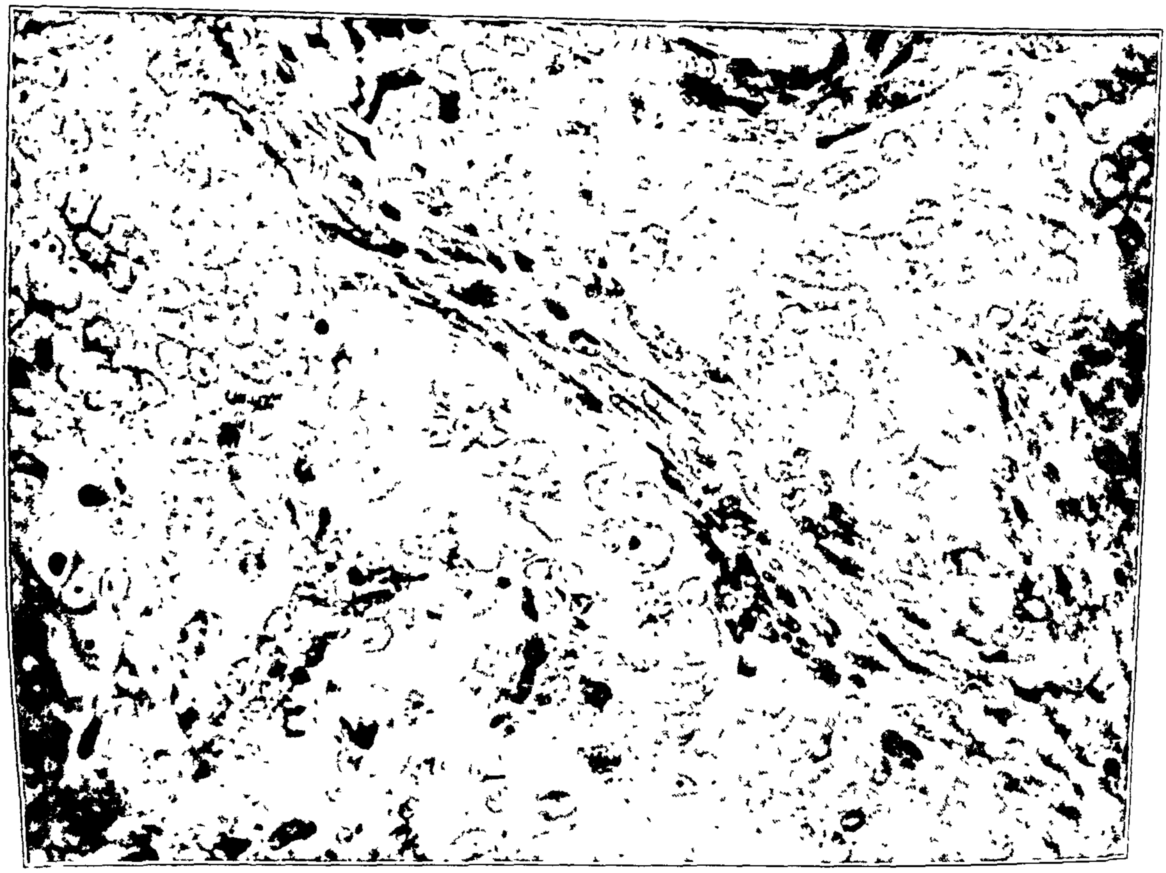

FIG. 39

Figs. 38 (× 65) and 39 (× 500). Case 15. The microscopic appearances of a highly characteristic malignant neoplasm of synovial origin. The complex pattern created by the elements supporting the connective tissue and the epithelial-like cells that form the tufts and clefts is well illustrated. (A.I.P. Acc. No. 93364.) (Case 16 possessed a similar microscopic structure.)

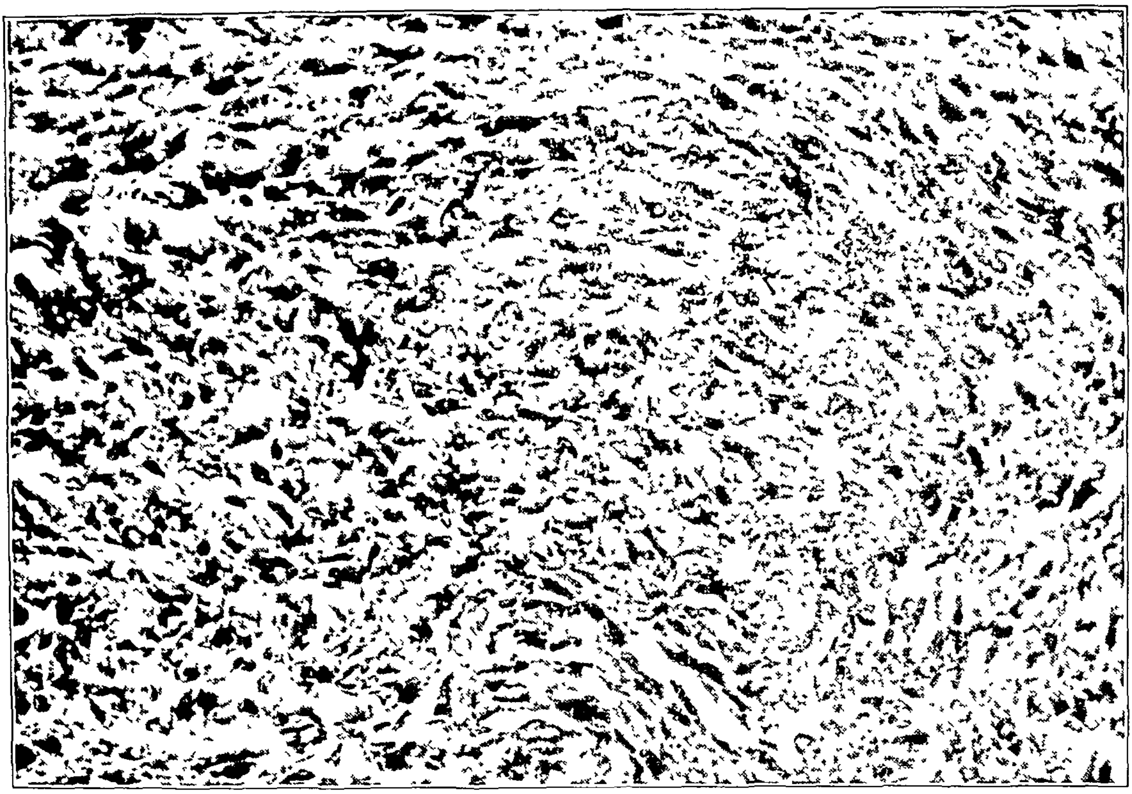

Fig. 23
Case 5. A highly cellular area (× 450) from the primary tumor illustrated in Figs. 19, 20, 21, and 22 is shown.

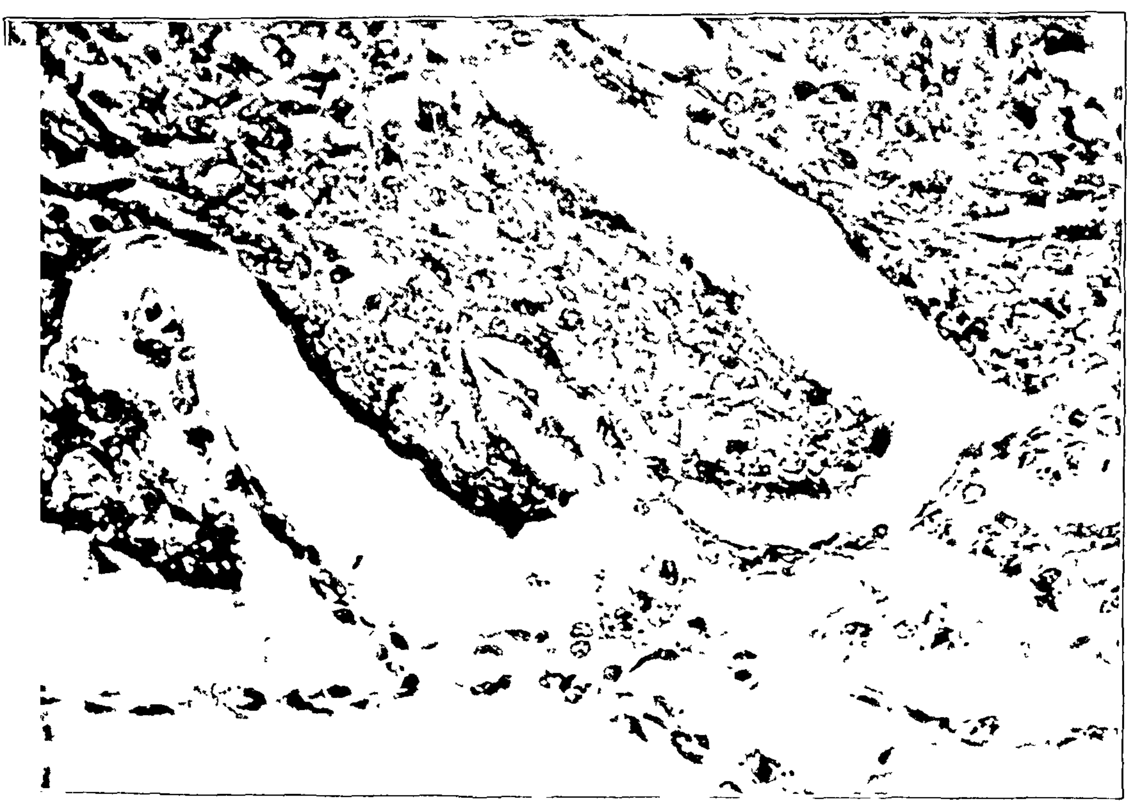

Fig. 24
A metastatic nodule in the lung is reproduced in this photomicrograph (× 150). Note the similar cytological and structural features in the primary and metastatic tumor nodules.

FIG. 42

FIG. 43 FIG. 44

Case 22. Low-power (× 55) and high-power (× 450) photomicrographs reveal spongy and solid portions of this neoplasm. In certain areas villous structures and tissue spaces are prominent, while in other areas the tumor shows only a slight capacity for the formation of the usual identifying structures.

The specimen from which these illustrations were made was a soft, pale mass, 3 centimeters in diameter, arising from and attached to the meniscus of the knee joint. The tumor promptly recurred after local excision, and the extremity was then amputated. (A.I.P. Acc. No. 113335.)

Fig. 25

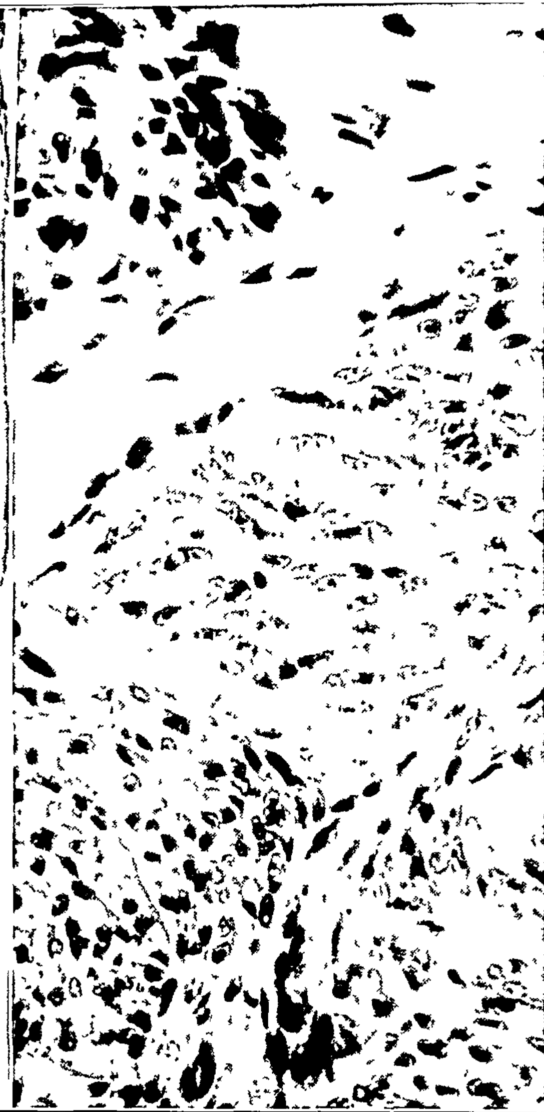

Fig. 26

Fig. 27

Case 6. Photomicrographs (× 145, ×500, and × 500, respectively) of the more solid and simplified type of sarcoma derived from synovial tissues. The nestlike accumulations of cells, with a distinct tendency for tufting and cleft formation, are features by which such tumors may be recognized. On gross examination this tumor was seen to be a firm mass, the size of a walnut, arising in the infrapatellar bursa of the left knee. (A.I P. Acc. No. 80133.)

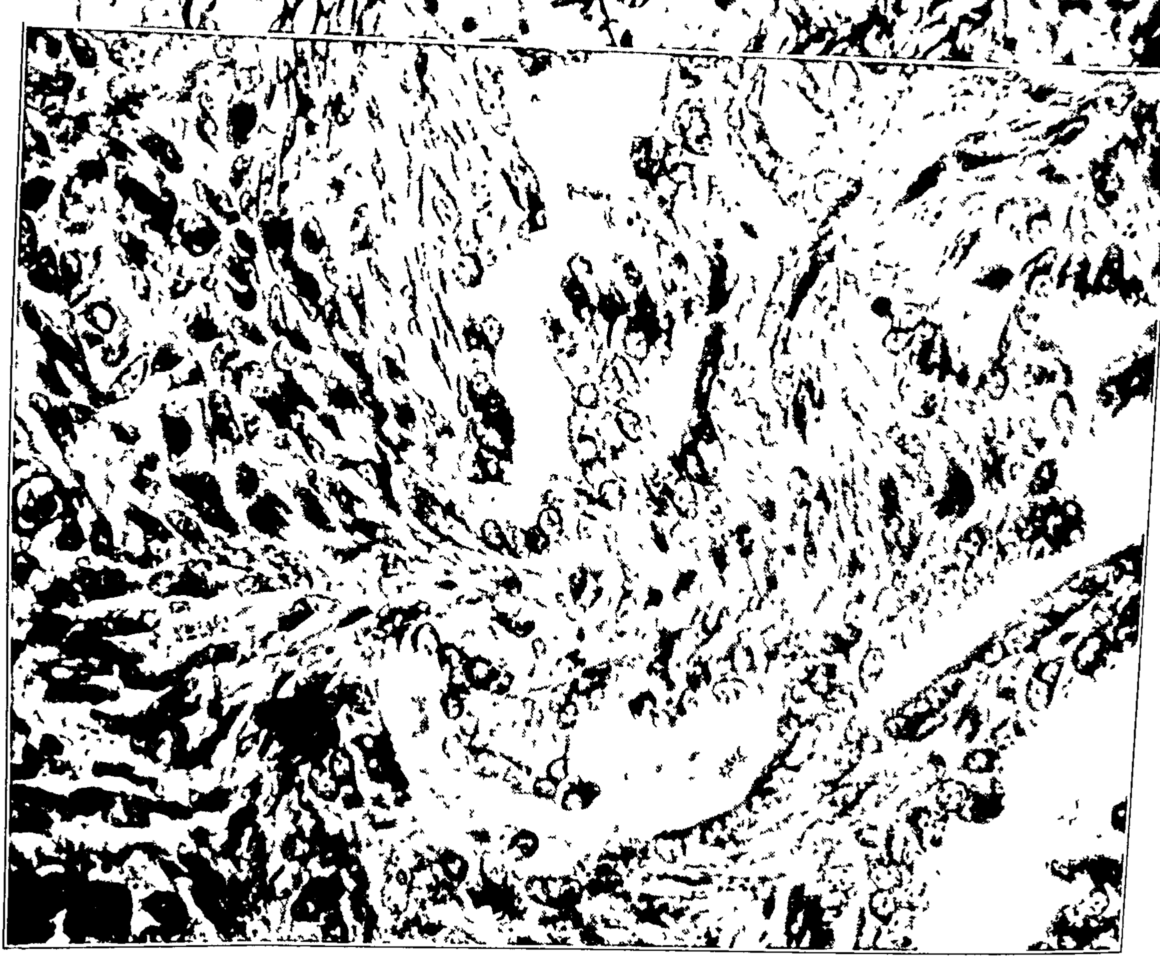

Fig. 47

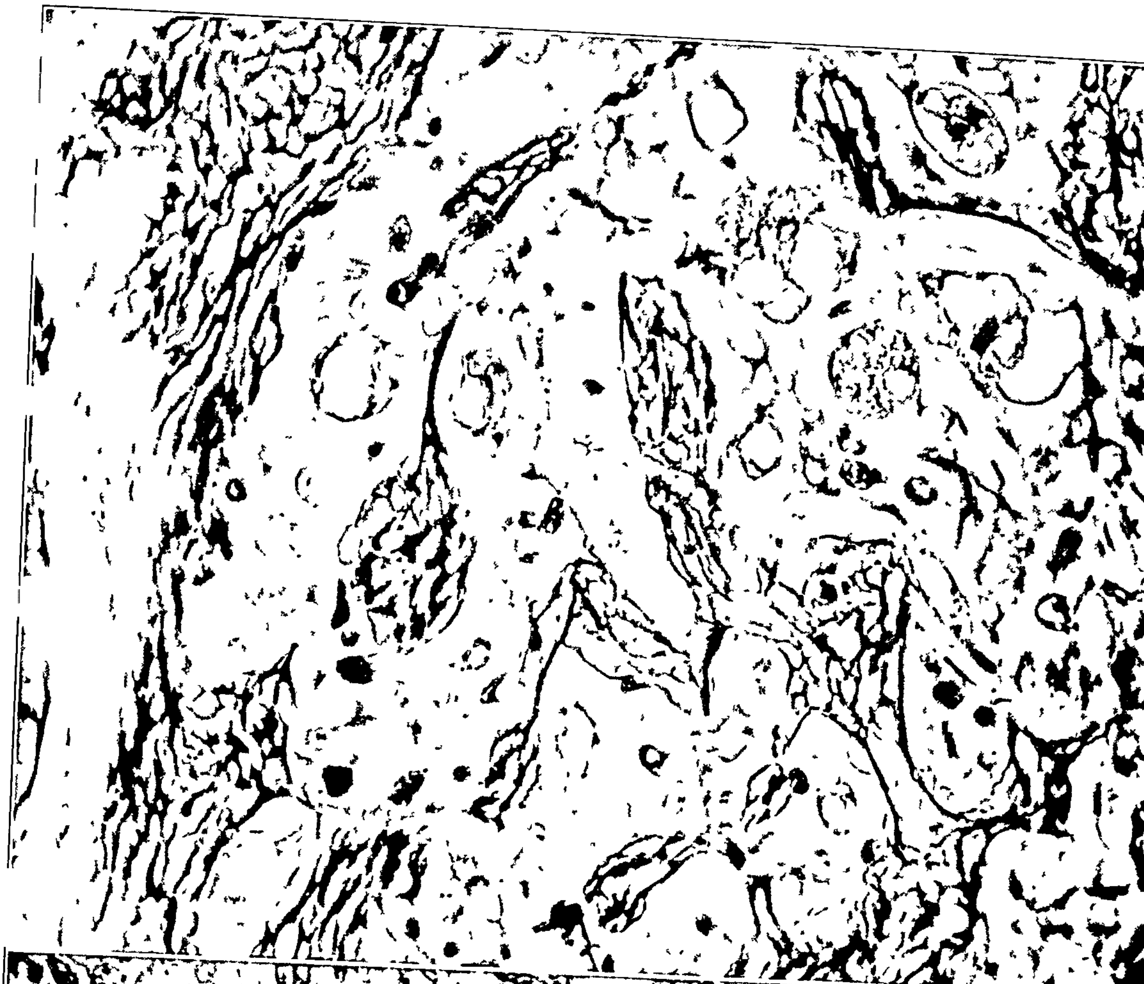

Fig. 48

These reproductions (× 500 and × 550) show in detail the structure of the tumor removed in Case 23 (Figs. 45 and 46). Fig. 48 reproduces the distribution of reticulum fibrils about the cells lining the glandlike structures.

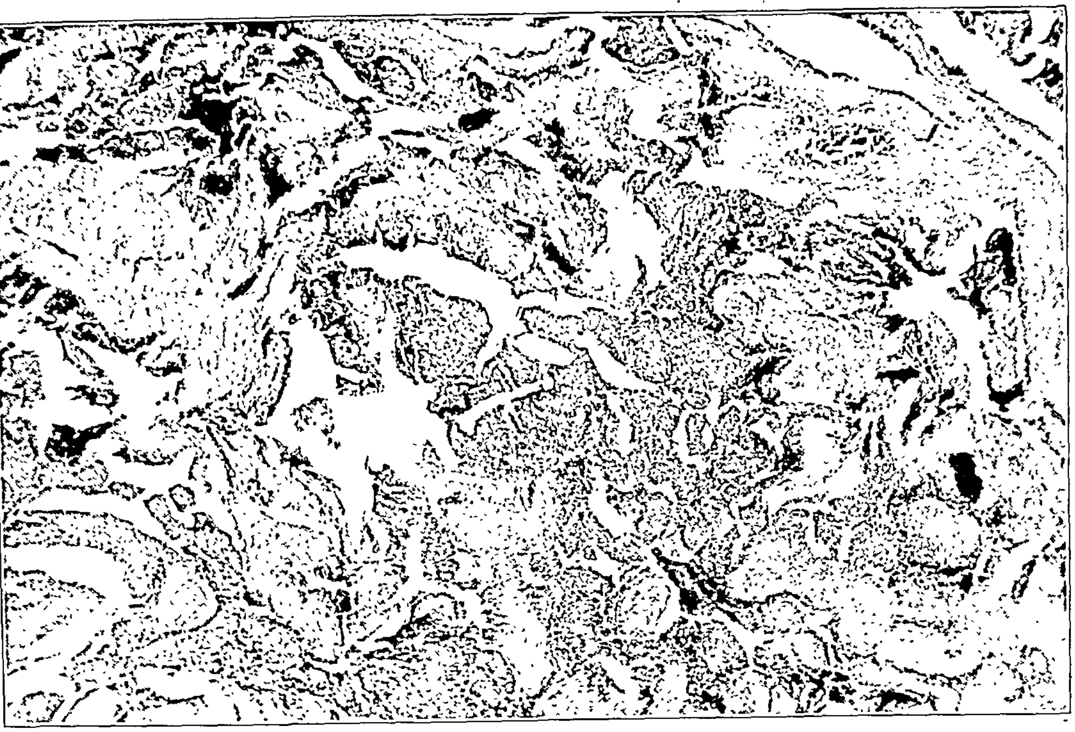

FIG. 30

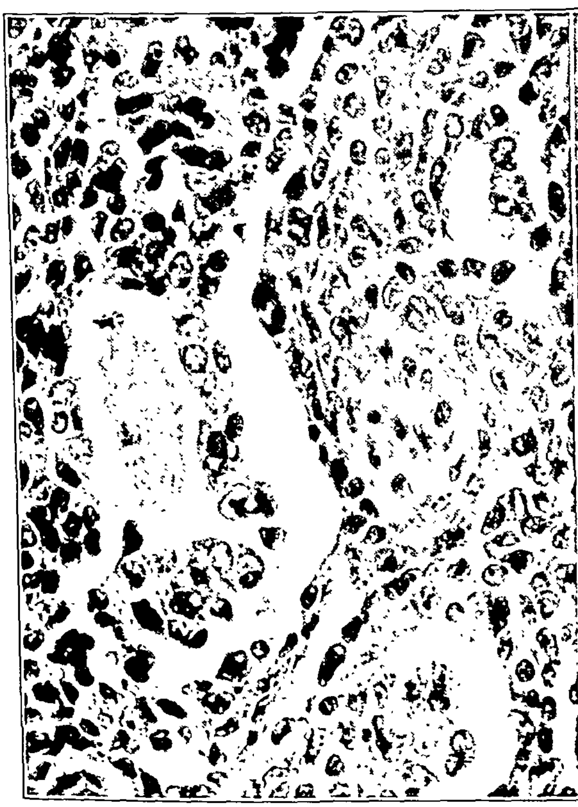

FIG. 31 FIG. 32

Case 11. Photomicrographs of different portions of a hemorrhagic, stringy-appearing tumor that measured 6 by 4 by 2 centimeters. Certain portions of the tumor were gray or gray-brown in color and friable. Coarse fibrous trabeculae were traversing the mass. The tumor was lateral to, and slightly above, the knee; and, although attached to the capsular tissues, it was external to the joint space. A trabeculated and villous structure is shown conspicuously in Fig. 30 (× 50); the characteristic glandlike spaces with secretion in Fig. 31 (× 450); and the equally characteristic villous tufting of cells in an extracapsular extension of the tumor in Fig. 32 (× 360). (A.I.P. Acc. No. 85248.)

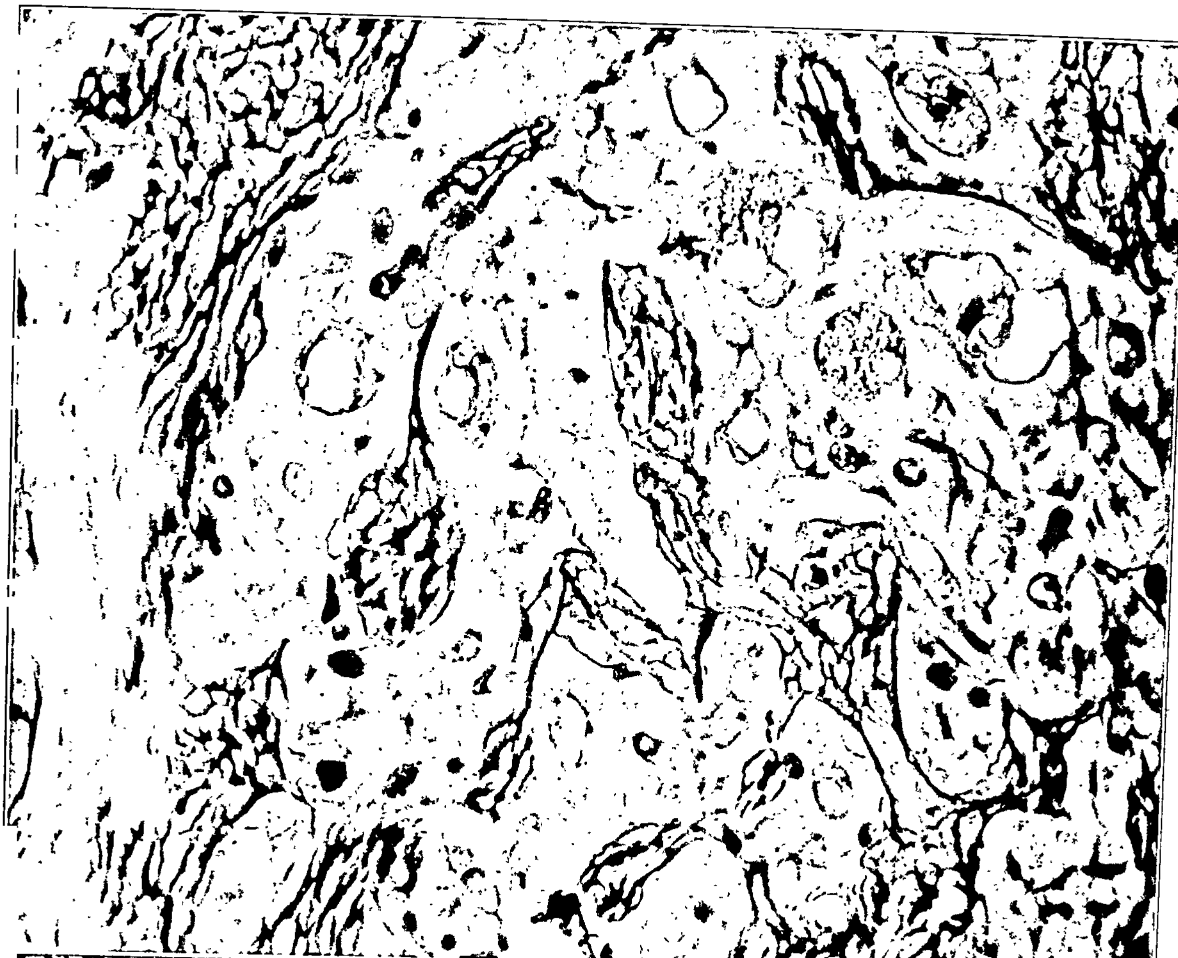

Fig. 48

Fig. 47

These reproductions ($\times 500$ and $\times 550$) show in detail the structure of the tumor removed in Case 23 (Figs. 45 and 46). Fig. 48 reproduces the distribution of reticulum fibrils about the cells lining the glandlike structures.

Fig. 35

Case 13. Neoplasm arising from and infiltrating the soft tissues of the leg of an infant. The tumor was present at birth, and grew rapidly until removal on the nineteenth day.

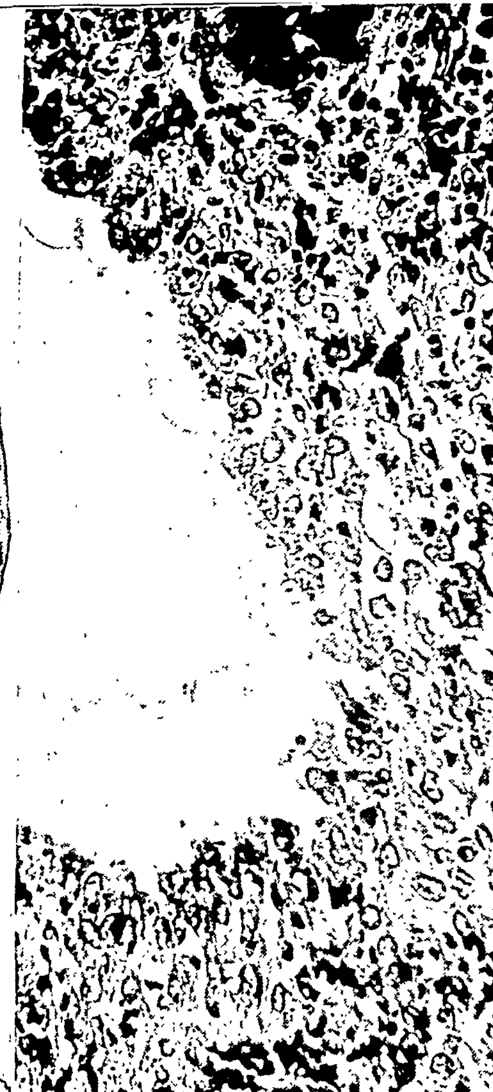

Fig. 36

Fig. 37

Case 13. Photomicrographs (× 360 and × 450), showing a cellular mesenchymal tumor in which there is distinct space formation, with marginal layering of cells and secretion into the clefts. Although the identifying histological features of this tumor are less convincing than in the other specimens recorded in the series, there is sufficient evidence of the reproduction of synovial-tissue structures to warrant its inclusion.

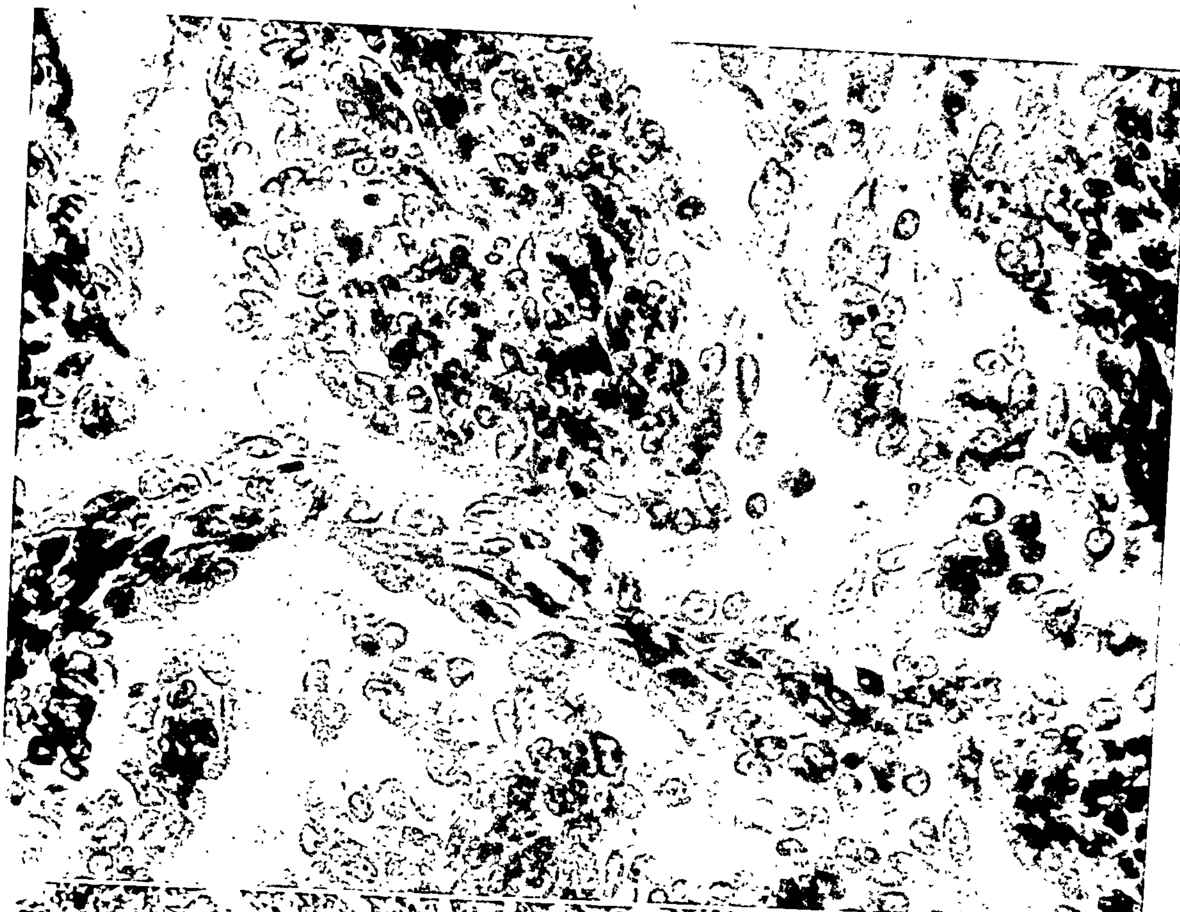

FIG. 52

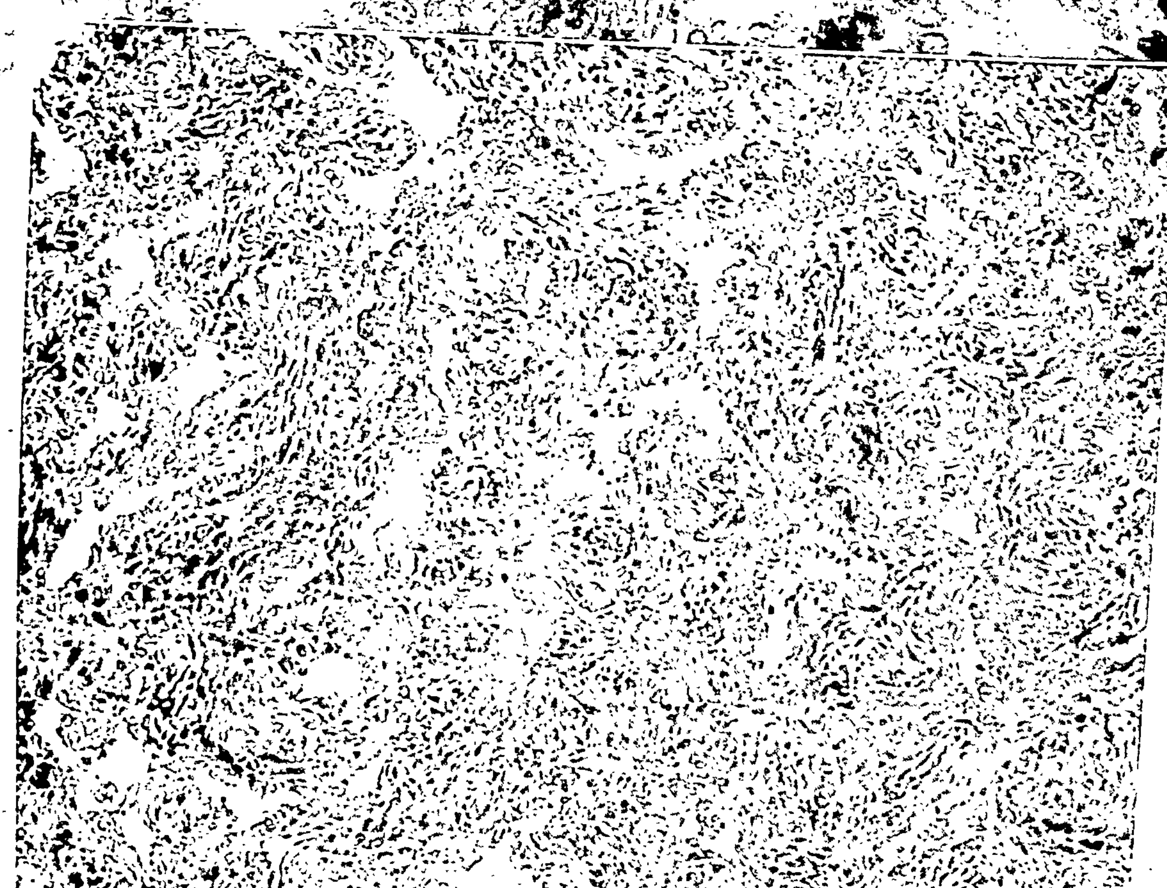

FIG. 51

Medium-power (× 200) and high-power (× 550) photomicrographs, showing the more characteristic features of the tumor illustrated in Figs. 49 and 50.

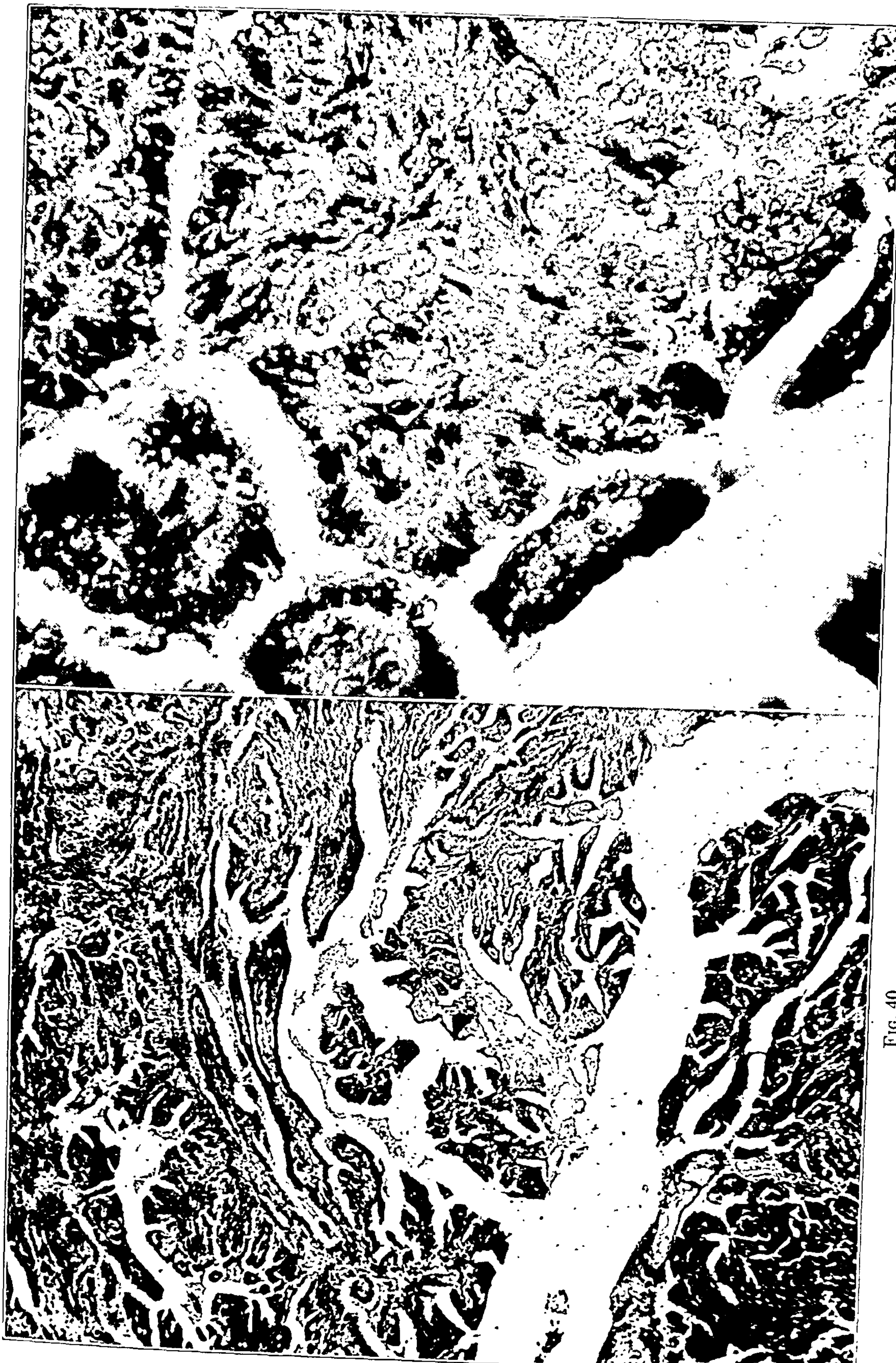

Fig. 41

Fig. 40

Case 21. The tumor represented by these reproductions ($\times 40$ and $\times 500$, respectively) was a lobulated, partially encapsulated mass, measuring 9.5 by 8.0 by 4.5 centimeters. It was removed from the upper thigh, beneath the inguinal ligament. Upon sectioning, it was friable, red-gray in color, and presented a granular surface. The formation of villi was exceedingly prominent in this specimen. (A.I.P. Acc. No. 114459.)

to the highly characteristic patterns of growth (Figs. 47, 48, 51, 52, 53, and 54). It was not feasible in this study to employ the *in vitro* culture technique described by Murray, Stout, and Pogogeff, although such studies would be a valuable adjunct in differential diagnosis.

The morphological features by which this group of neoplasms may be recognized are illustrated in Figures 14 through 54. It will be seen that three basic patterns exist and are developed with varying degrees of clarity.

One pattern is represented by the formation of tissue spaces which vary from slitlike clefts to well-defined glandlike spaces containing serous or mucinous fluid (Figs. 15, 16, 28, 29, 33, 34, 40, and 41). The second major design is the formation of cell tufts. This feature varies from compact groups of oval or polygonal cells segregated in solid portions of the tumor tissue to papillary projections extending into the clefts and glandlike spaces (Figs. 25, 26, 27, and 43). The third architectural design that is noted in the more highly characteristic tumor is the reproduction of epithelial-like cells upon a supporting stroma of compact tissue, formed of elongated cells with small dark nuclei (Figs. 38, 39, and 48).

The perfection with which these microscopic patterns are developed varies within wide limits. In a given example, one such design may be well developed, while the others are minimal and may require specially stained preparations to bring them into relief.

It will be noted, however, that these morphological features represent the basic structural and functional characteristics of synovial tissues. The ease with which the derivation of the neoplasm is established depends upon the clarity with which the normal patterns are reproduced. Although mitotic figures are seen in varying numbers, it seems doubtful if their frequency is a reliable index of the degree of malignancy of the neoplasm.

Microscopic examination should include the study of several well-selected blocks of tissue. Single tissue blocks may resemble a benign synovial-membrane lesion (Fig. 21), or may contain abundant fibrous connective tissue with or without fatty detritus and calcium deposits (Figs. 22 and 30). Extension of the tumor tissue into vascular channels or tissue clefts beyond its gross margins (Fig. 32) should be looked for.

The cellular and structural features of the primary tumor are usually reproduced in the metastatic lesions in the lungs and other organs (Figs. 23, 24, 53, and 54).

DISCUSSION

It is not the purpose of this paper to state the possible relationship of non-neoplastic swellings or benign tumors of joints, bursae, and tendon sheaths to the malignant lesions that are described. It seems proper, however, to draw attention to the difficulties that may be experienced in distinguishing between benign and malignant neoplasms of these tissue components. Furthermore, it should be noted that there is historical evidence suggesting that in some instances at least, a malignant tumor (synovioma) may develop in or near a joint or some other synovial-lined structure that has been swollen or otherwise abnormal for many months or years. It is highly desirable, therefore, to follow for subsequent analysis all patients from whom benign neoplasms or other tumor-like lesions of synovial tissues have been removed. Such a study of the vast amount of material now registered with the Army Institute of Pathology should give more precise information on the possible dangers of benign lesions acquiring malignant qualities, as well as provide histological criteria which would sharply delineate between the innocent lesions and those that are potentially dangerous.

The usual treatment employed in this series was local excision, followed in many instances by wider excision or amputation at a considerably later date, and is thus essentially like that reported in previous studies in which the fatality rate from metastases has been exceedingly high.

Because of the demobilization procedures in effect since the termination of the War, it has not been possible to obtain recent follow-up information in many of the cases in the

Fig. 45

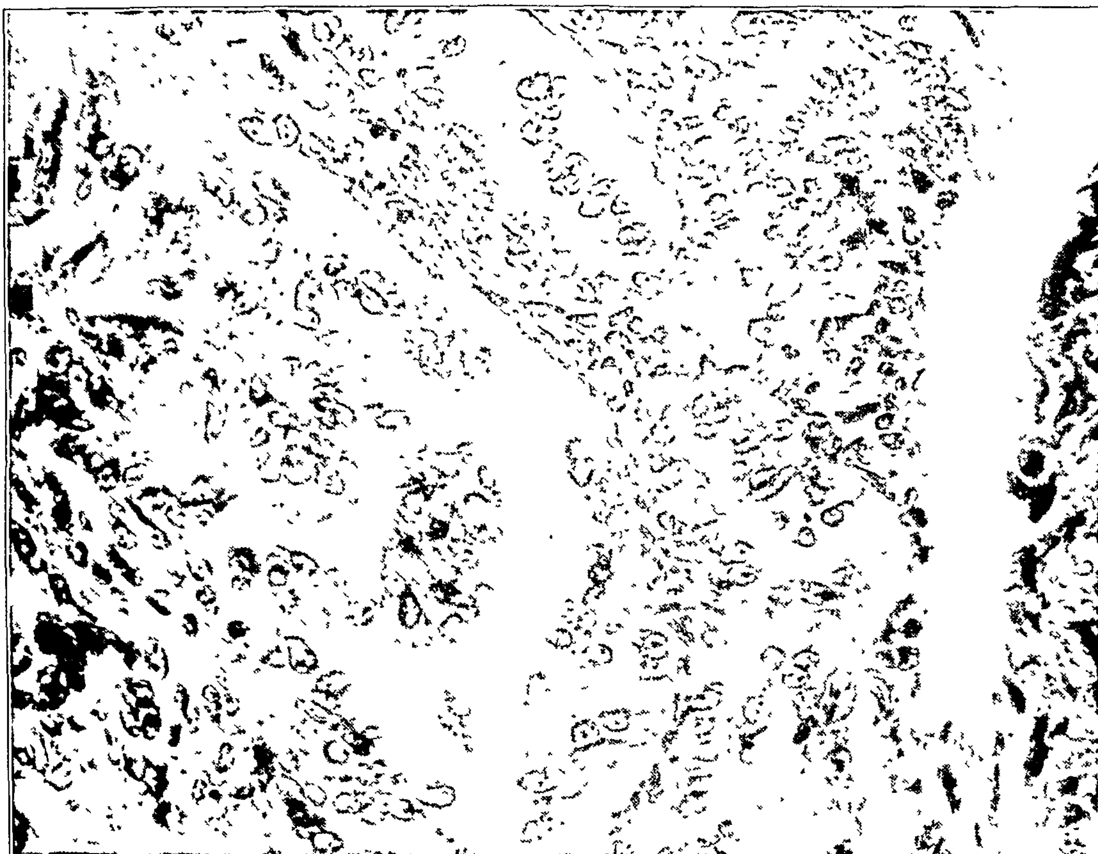

Fig. 46

Case 23. Low-power (× 125) and high-power (× 550) photomicrographs, showing the microscopic structure of a typical synovial sarcoma (synovioma) that arose from the intermuscular connective tissues of the thigh and popliteal space. Grossly, the tumor was lobulated and made up of red-gray cellular masses, bound together by dense fibrous tissue bands. The adjacent fat and muscle had been infiltrated. (A.I.P. Acc. No. 105488.)

ORGANIZERS AND THE GROWTH OF BONE *

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From the Department of Anatomy, University of Louvain

The primary causes of bone growth still remain one of the chief and partly unanswered questions in bone and joint physiopathology. A certain amount of work has been done recently in this field, the results of which cast some light on the problem. We hope that a summary of this research will induce other workers to plan their experiments along similar lines.

THE PERICHONDRIAL BONY RING OF THE OSSIFICATION GROOVE

First of all, as a necessary introduction for the description of the experimental findings, we have to consider the structure of a young growing bone near its growth cartilage. Figure 1 represents the distal extremity of the radius of a rabbit, seventy-five days old, and Figure 2 shows a part of the same extremity at a higher magnification. Under the attachment of the periosteum, in the ossification groove (Ranvier's *encoche d'ossification)*, is a thin bony lamella, which, of course, is the section of a ring presenting two faces and two edges. Its central face is in close contact with the growth cartilage and the outermost trabeculae of endochondral bone. Its peripheral face is separated from the periosteum by a thick layer of periosteal cells. Its epiphyseal edge is free and shows signs of intense osteogenesis. Its diaphyseal edge is also free and is being absorbed by osteoclasts. Growth and absorption are going apace, for the height of the ring remains approximately the same during development. This ring might be called "the perichondrial ring of the ossification groove"; the expression is somewhat lengthy, but it has the advantage of being self-explanatory.

The formation of this ring is easily understood, if one follows the growth of the diaphysis from its earliest stage. In its most primitive form the diaphysis is represented by a bony tube, developed around the cartilaginous anlage at the time when the cartilaginous cells are beginning to hypertrophy and are on the verge of being invaded. This tube is continuous from end to end, but after a while its extremity is cut off from the middle part by osteoclasts and becomes the perichondrial ring. The faster the growth of the cartilaginous epiphysis, the sooner the extremity of the tube is isolated. From that time on, the extremity of the shaft is made of two elements: One is the perichondrial ring of the ossification groove; the other is the endochondral trabeculae which merge, on the one hand, into the peripheral parts of the growth cartilage, and, on the other hand, are continuous with the middle part of the shaft. It goes without saying that, if followed toward the diaphysis, the endochondral bone is seen to be transformed gradually into periosteal bone.

The process is linked with the tubulization phenomenon by which the metaphysis is continuously remodeled. It is well known that the metaphysis must reduce its outer diameters so that the long bone will retain its typical proportions during growth. What was unknown, surprising as it may seem, is that the process entails the cutting off of the extremity of the primitive diaphysis and the continuation of its own evolution in the ossification groove.

Almost any other growing extremity of a long bone of a rabbit (except the region where the patellar tendon is inserted into the tuberosity of the tibia) might have been chosen to show the ring described. We have not yet had the opportunity of studying human bones from this point of view (and we wish that someone with the necessary collection at

* Summary of a lecture delivered before the St. Thomas's Hospital Medical School at the invitation of the University of London, June 6, 1946.

Fig 49

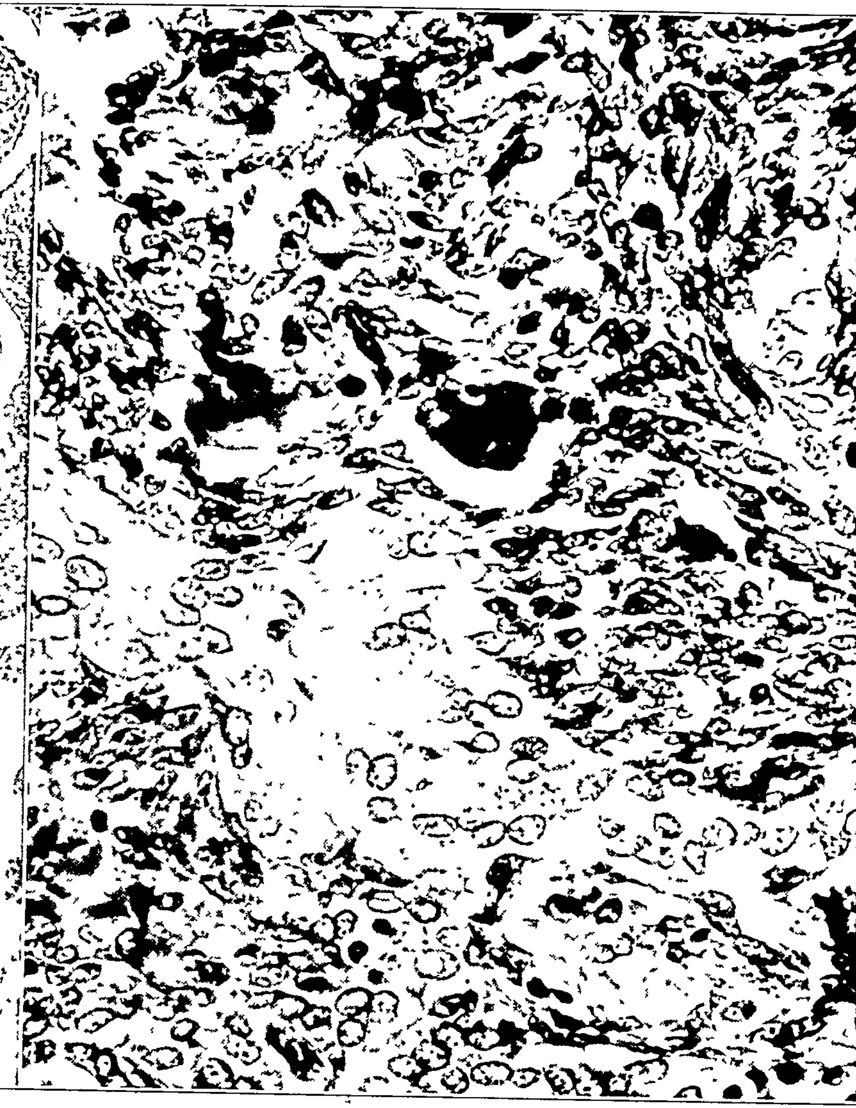

Fig 50

Fig. 49: Case 29. A low-power (× 65) photomicrograph of the fibrous capsular wall of an invasive tumor, arising in the deep fascial tissues of the left thigh. Note the cystic areas and the highly cellular tissue lining the fibrous trabeculae (A I P. Acc No 97736)

Fig. 50: The interlacing bundles of oval and spindle cells illustrated in previous figures and the hyaline material in tissue spaces are in evidence. (A I.P. Acc. No. 97736.)

upon the growth cartilage. As to the nature of the phenomenon involved, it may be considered as an instance of induction. One cannot be too cautious in using such a word; it should not be used for the mere production of new tissue, but reserved for the cases where this new tissue shows a definite tendency to be organized *in a structure similar to the normal.* Our experimental results meet exactly this requirement.

ASSIMILATORY INDUCTION OF THE ENDOCHONDRAL OSSIFICATION

Yet another instance of an induction phenomenon in bone growth is provided by the following experiments: A rod of hyaline cartilage was taken from the rib of a rabbit and

FIG. 3

FIG. 4

FIG. 3: Shows perichondrial ring, one month after homotransplantation of the central part of the distal growth cartillage of the radius into the brain (× 80). (*Reproduced, by permission, from Anat. Rec., 92: 439, 1945.*)

FIG. 4: Homotransplantation of a rod of hyaline costal cartilage into the upper extremity of the tibia was done in such a manner that the graft pierced the growth cartilage. Four months later the graft was the seat of an endochondral ossification (× 36). (*Reproduced, by permission, from Bull. Acad. Roy. de Méd. de Belgique, 10: 523, 1945.*)

put into the upper extremity of the tibia of another young rabbit in such a manner that it pierced the center of its proximal growth cartilage. The latter, in spite of its having been wounded, went on proliferating; and a close contact was established between the grafted cartilage and the growth cartilage. After a few weeks the grafted cartilage was the site of a typical endochondral ossification (Fig. 4). The serial sections proved that the phenomenon did not follow an invasion of the graft by the host cartilage cells, but that it was the consequence of the contact of both tissues. The growth cartilage behaved as an inductor and imposed its organization upon a tissue which, had it been grafted alone anywhere else, would have remained a piece of hyaline cartilage. Such a process may safely be considered as one of assimilatory induction.

EXTRACTION OF AN OSTEOGENETIC SUBSTANCE FROM THE GROWTH CARTILAGE

The two previous groups of experiments are clear-cut evidence of the part played by induction at a much later stage than one would ever have thought. They point strongly

Fig 49

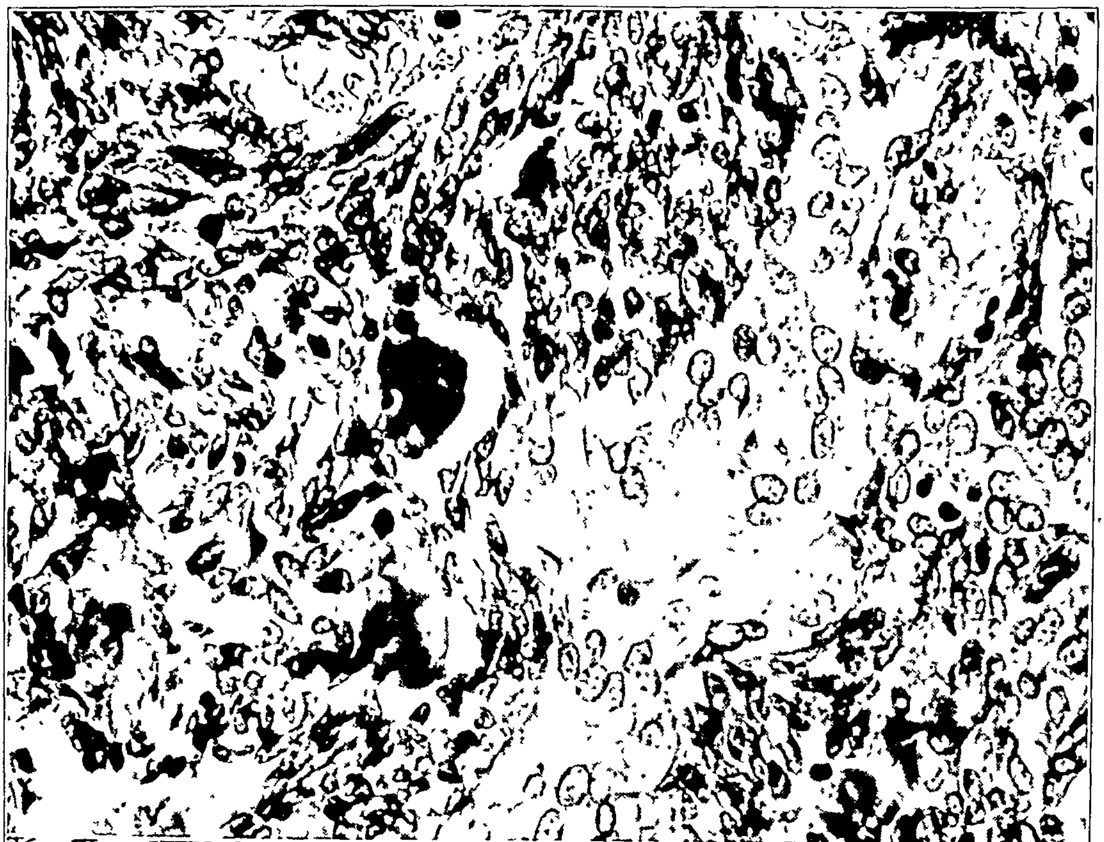

Fig 50

Fig. 49: Case 29. A low-power (× 65) photomicrograph of the fibrous capsular wall of an invasive tumor, arising in the deep fascial tissues of the left thigh. Note the cystic areas and the highly cellular tissue lining the fibrous trabeculae (A.I.P. Acc. No 97736.)

Fig. 50: The interlacing bundles of oval and spindle cells illustrated in previous figures and the hyaline material in tissue spaces are in evidence. (A.I.P. Acc. No. 97736.)

histological examination revealed the presence of all the structures which may be analyzed in a growing long bone: growth cartilage, with its characteristic row arrangement and partially surrounded by a perichondrial ring of the ossification groove (Fig. 5); tubular diaphysis, enveloped by periosteum and containing a functional hemopoietic marrow (Fig. 6), *et cetera.*

OTHER INSTANCES OF THE ROLE PLAYED BY AN ORGANIZER IN OSTEOGENESIS

For their proper evaluation, the foregoing experiments, all of which were performed by the author, should now be put against a background provided by related facts.

Levander, in 1938, was the first to get osteogenesis or chondrogenesis with an alcoholic extract of fracture callus as well as of normal bone. Similar results were reached by his pupil, Annersten, in 1940. In 1944, Bertelsen also obtained positive results with extracts of bone marrow, bone tissue alone, periosteum, and bone extremities, including epiphysis, growth cartilage, and metaphysis. Judging from the illustrations published by the Scandinavian authors, none of their results, fundamental as they are, can compare, as far as the degree of organization is concerned, with the results observed with extracts of epiphyses treated at a stage when they are still entirely cartilaginous. Consequently we want to stress that this tissue seems to offer better prospects for future research.

In a recent paper (1946), the author studied the osteogenetic properties of the periosteum and collected some new facts, which seem to prove that not only the organization of a skeletal piece, but also the osteogenesis produced by the periosteum, is under the influence of an organizer. According to Bertelsen there is little doubt that the same conclusion must be extended to the osteogenesis produced by bone marrow and by a bone graft.

We believe that these experiments permit us to view, at last, the problem of osteogenesis from the right standpoint: It is an embryological problem which must be dealt with accordingly,—that is, with embryological hypotheses and methods. Results obtained so far warrant further research in the same direction. Practical applications, if any, will have to be considered after the main subject is better known.

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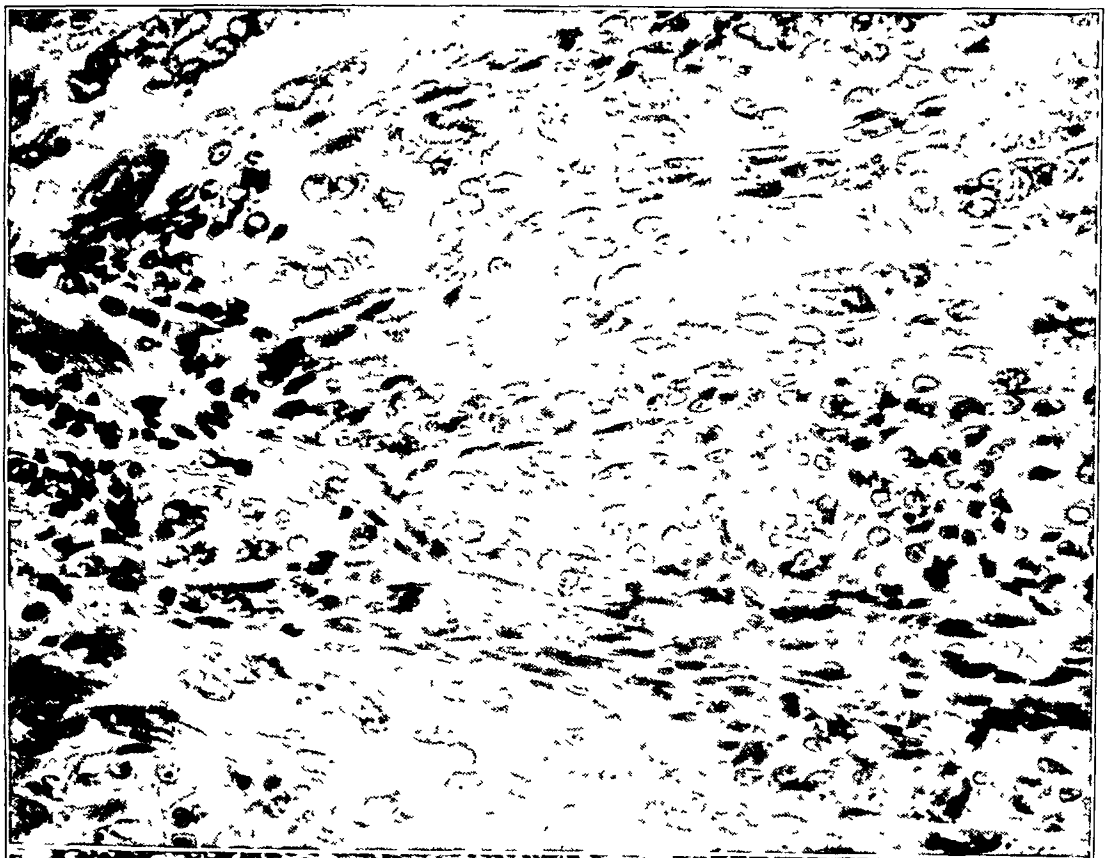

Fig. 54

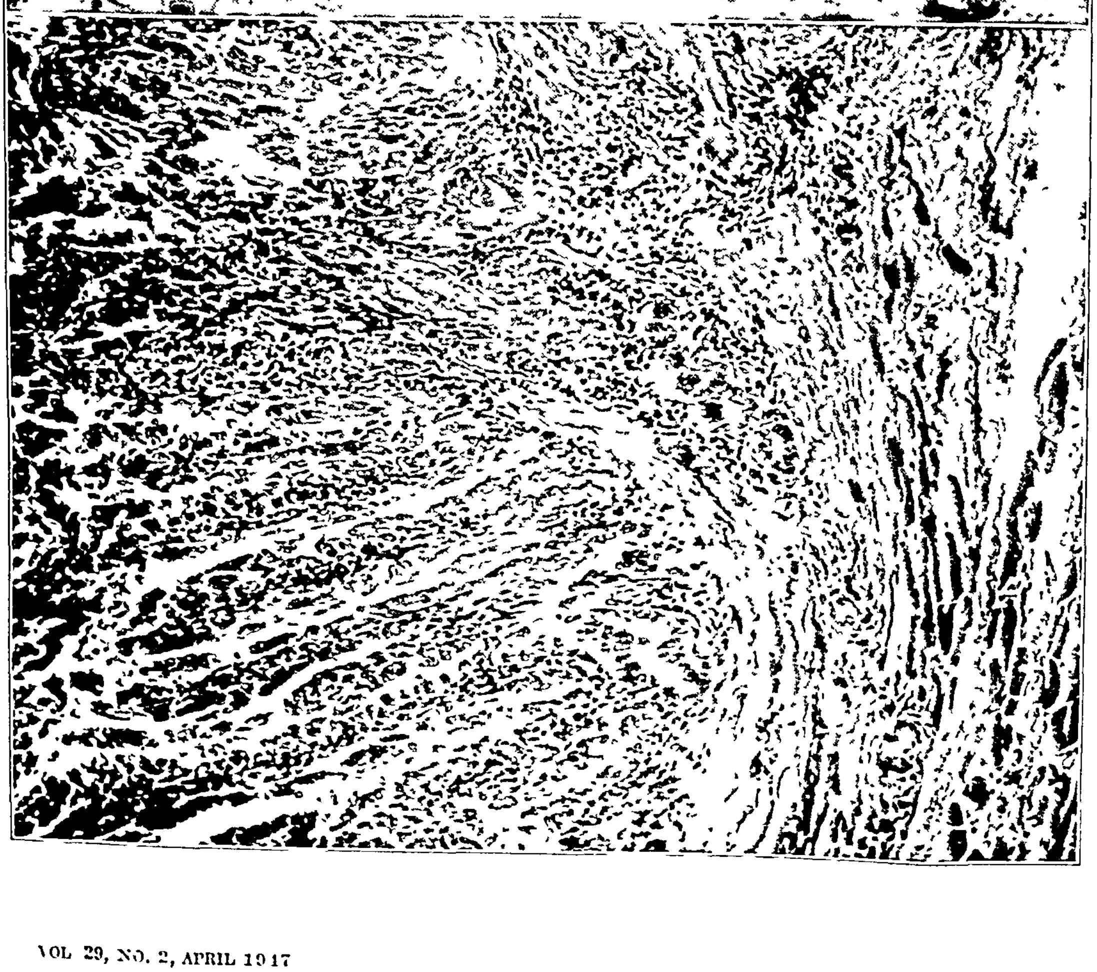

Fig. 53

Fig. 53. Case 29. The margin of a metastatic tumor nodule in the heart. The essential structural and cytological features of the primary tumor are present in this metastasis (× 175). (A.I.P. Acc. No. 97736.)

Fig. 54. The cellular detail (× 550) of the metastatic nodule illustrated in Fig 53.

Figs 53 and 54 should be compared with the reproductions of the primary tumor from Case 29. (See Figs. 49, 50, 51, and 52.)

TABLE I

SITES AND TYPES OF FRACTURES ENCOUNTERED IN A SERIES OF SIXTY METATARSAL MARCH FRACTURES

	Number	Per Cent
Side of lesion		
Right only	24	40
Left only	30	50
Bilateral (right 3, left 3)	6	10
Total	60	100
Total right	27	45
Total left	33	55
Total	60	100
Metatarsal fractured		
First	1	1.6
Second	32	53.4
Third	27	45.0
Total	60	100.0
Segment of metatarsal fractured		
Proximal third	9	15
Middle third	22	36
Distal third	29	49
Total	60	100
Type of fracture		
Displaced	5	9
Complete but not displaced	35	58
Incomplete	20	33
Total	60	100

be made more accurately on the basis of these findings than on the basis of roentgenographic examination. In several instances, roentgenographic examination, which was initially negative, later revealed the fracture at the suspected location. Pain on flexion of the toe of the fractured metatarsal was an almost universal finding.

Table I presents data concerning the side of the lesion, the metatarsal involved, the segment of bone fractured, and the type of fracture encountered. The higher incidence of fractures of the left foot, which differs from most reports, is surprising. In our series of sixty patients there were three instances of bilateral metatarsal fractures. Table I deals only with the sixty metatarsal fractures. In addition, three patients who presented march fractures elsewhere were studied; one had a fracture of the ischium, another of the distal end of the tibia, and the third of both calcanei. The findings in these three cases were the same as those described in the literature for similar lesions.

ETIOLOGICAL STUDY

To ascertain the relative importance of certain causative factors, a comparative study of the group with march fractures and of an equal number of carefully selected controls was made. Sixty soldiers from the Mars Task Force who had completed at least 200 miles of the same forced march, without foot complaints, were selected. These soldiers, chosen from the medical wards of the Hospital, had been admitted for diseases not involving the musculoskeletal system.

There were no significant differences between the two groups in the following factors: (a) age, (b) height, (c) weight, (d) weight of load carried, (e) previous occupation, (f) family history of foot trouble, and (g) type of shoe worn. Differences between the two groups are shown in Table II.

As the soldiers with march fractures began to arrive, we were impressed with the inadequacy of their foot training in preparation for such a mission. In order to evaluate the relative importance of this factor in the production of fracture, an attempt was made to compare their training with that of the control group. A minimum of two four-mile

present series. No progress notes have been obtained from eight patients. It is known, however, that eleven of the patients died with widespread metastases. In two additional patients, metastases are known to be present; and in three others, recurrences have been reported. It appears probable, therefore, that the follow-up study now in progress will only re-emphasize the well-known fact that these tumors end fatally in a high proportion of instances when treated by the conventional methods. However, as has been forcefully stated by Haagensen and Stout, the usual location of this tumor in an extremity and its tendency to remain localized for considerable periods of time are factors of great advantage to the surgeon. If the present discouraging death rate is to be improved, there must be closer cooperation between the surgeon and the pathologist. The pathologist must develop skills and techniques which will enable him to interpret these lesions properly, and the surgeon must take the necessary means to eradicate the local lesions without resorting to preliminary conservative measures.

SUMMARY

Among the many lesions removed surgically from synovial-lined structures and registered with the Army Institute of Pathology during the years of the second World War were thirty-two examples of the malignant neoplasm usually designated as *synovioma.*

Certain cytological and structural features distinguish this type of neoplasm from other mesenchymal tumors. These cell patterns may be explained by referring to the anatomical and physiological peculiarities of the normally developing and mature synovial tissues.

Although the determination of the fatality rate in the present series must await the completion of the follow-up study which is now in progress, the knowledge that sixteen patients have died, have had metastases, or have shown local recurrences, points again to the seriousness of this neoplasm, as well as to the necessity for its prompt and complete surgical removal.

The present observations indicate a need for a follow-up study of the many cases in which synovial-membrane lesions, now regarded as benign, have been removed. Such an investigation should aid in determining the future course of these lesions of varied histological patterns and thereby serve as a guide for appropriate treatment.

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expressed as "minus" in millimeters. Of the march fracture group, there were "plus" measurements in 89 per cent. of the cases; of the control group, in 66 per cent. In the fracture group the average of all these relative measurements was plus 2.9 millimeters; whereas, in the control group, the average was plus 1.6 millimeters. Although a majority of both groups thus showed a relatively short first metatarsal, both the number and degree of involvement were greater in the series with march fractures.

The moderate difference between the control and the fracture groups, as regards history of previous foot complaints, is not statistically significant.

TREATMENT

In every case the metatarsal fracture was immobilized in a plaster boot, with attached walking iron, until there was roentgenographic evidence of bony union. On the average, five or six weeks were required. The patients were then sent to the convalescent section of the Hospital for intensive foot reconditioning.

RESULTS

The cases were followed for approximately five months, and the results of treatment were generally unsatisfactory. Persistent foot complaints considerably prolonged hospitalization. In spite of good clinical and roentgenographic evidence of bony union in every case, only half of the soldiers returned to combat duty.

The frequency of march fractures in the expedition of the Mars Task Force resulted in a considerable loss of manpower. Because combat soldiers were involved, the military loss was particularly costly. We believe that proper preliminary foot conditioning would have prevented most of the fractures.

SUMMARY

1. Sixty patients with typical march fracture are compared with a control group of sixty patients without march fracture. Both undertook the same 300-mile march with the Mars Task Force through rough terrain in Burma.

2. No significant differences between the two groups were noted in age, height, weight, weight of the load carried, previous occupation, family history of foot trouble, and type of shoe worn.

3. The incidence of previous foot complaints, pes planus, ankle valgus, and a relatively short first metatarsal was greater in the march fracture group.

4. The intensity of preliminary foot conditioning was the most significant difference between the two groups.

5. March fracture occurs in a structurally inadequate and improperly conditioned foot as a result of functional overloading. We believe inadequate conditioning was chiefly responsible for the high incidence of fracture in the group reported.

his disposal might do so), but this description holds good for a few mammals taken at random.

THE FORMATION OF THE PERICHONDRIAL RING AS AN INDUCTION PHENOMENON

In this series of experiments, the central part of a growth cartilage has been grafted into a variety of organs and its evolution studied by histological examination. Following is an example of the results.

In a nine-day-old rabbit, the distal growth cartilage of the radius was cut off with a sharp knife by making two transverse and parallel sections; its whole peripheral region was then taken away by cutting four sections at right angles. The disc-shaped growth zone was thus reduced to a small cubic piece, consisting exclusively of cartilaginous tissue without any remnant of the ossification groove. A hole was drilled in the parietal bone of a rabbit of the same litter, and the graft was pushed into its brain.

One month later the graft was recovered and studied in serial sections (Fig. 3). It had produced a large quantity of endochondral trabeculae, which were being absorbed and replaced by hemopoietic marrow. All around the cartilage, cells which seemed to be ordinary fibroblasts had gathered. Some of these cells had taken part in the formation of a thin bony lamella, surrounding and flanking the growing cartilage. The bony lamella was growing by its epiphyseal edge and was being absorbed by its other edge. It was identical with the normal perichondrial ring of the ossification groove (Fig. 2).

The formation of this ring is thus a phenomenon which depends, directly or indirectly,

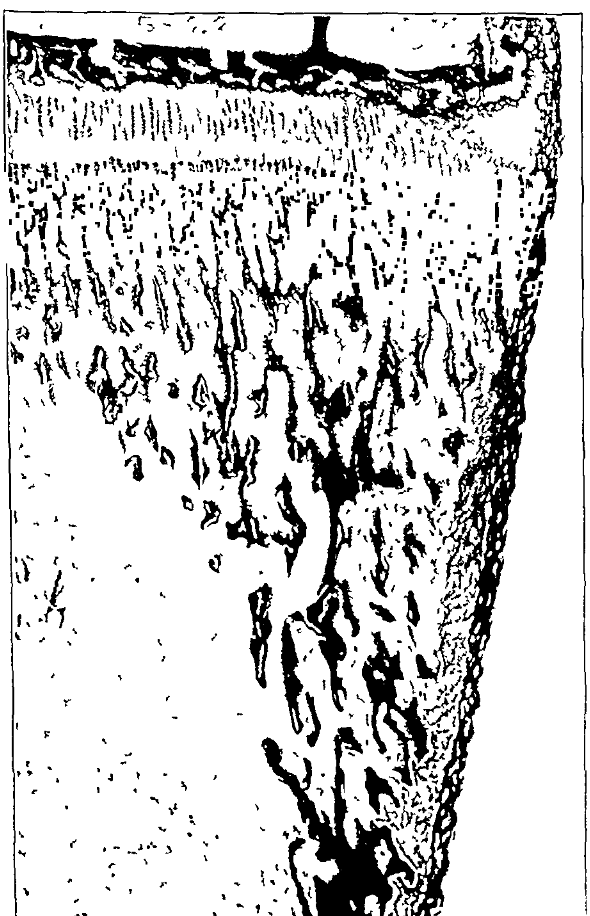

FIG. 1

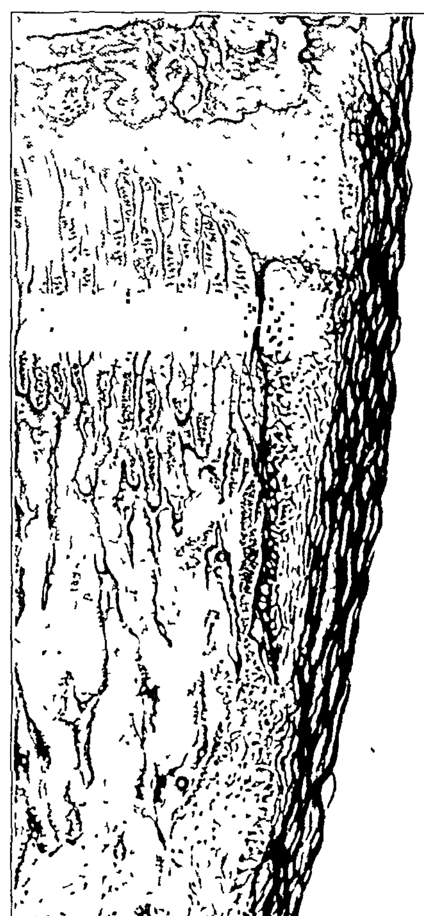

FIG. 2

FIG. 1 Distal extremity of the radius of a rabbit, seventy-five days old. Longitudinal section demonstrates the general relationship of the ossification groove (× 24).

FIG. 2. A portion of the same section at a higher magnification, showing the perichondrial ring of the ossification groove (× 56). (*Reproduced, by permission, from Anat. Rec., 92: 439, 1945.*)

Immediately after removal of the limb, 2 cubic centimeters of dye solution was injected into the ankle joint. The needle was inserted at the angle between the medial malleolus and the distal end of the tibia, and the joint was flexed and extended six times to disperse the dye.

The knee joint was opened at 5:40 P.M. by a transverse suprapatellar incision. The superficial fascia on both the medial and lateral aspects of the joint was stained. On deeper incision, synovial membrane, stained blue, was seen on both the medial and lateral aspects of the limb.

Inspection of the joint cavity showed that all parts had been stained. The color range was from a navy to a pale blue. The most intense staining was about the site of injection. The posterior and lateral walls of the suprapatellar synovial pouch and the lateral half of the patellar articular surfaces were accordingly the most deeply stained parts of the joint.

The lower part of the joint had been stained less deeply. The synovial membrane of the infrapatellar fatty pad and cruciate ligaments was a pale blue. The articular cartilage of the femoral and tibial condyles was also stained a pale blue. In the region of the menisci it was even paler, although the free margins of the menisci were quite markedly stained.

The residual dye was next removed by means of a needle and syringe, and the joint was washed out repeatedly. The manner in which the reclaimed dye was treated will be discussed later.

The ankle joint was opened at 9:30 P.M., and the residual dye was recovered as before. The entire synovial lining, as well as the articular cartilages, had been stained a very dark blue, and contrasted strongly with the paler blues of the knee joint.

The talus was next removed. The unstained tissues of its calcaneal and navicular articulations served as a measure of comparison and control.

Colorimetric Determinations

The fluid from the knee joint (about 3 cubic centimeters) and the washings were made up to a volume of 100 cubic centimeters, and compared with a suitable standard. The residual trypan blue, which was free in the cavity, amounted to 0.80 milligram. *This represents a recovery of 1.2 per cent. or, conversely, an absorption or fixation of 98.8 per cent.* of the dye originally injected.

The fluid from the ankle joint (about 2 cubic centimeters) and the aspirated washings were made up to a volume of 100 cubic centimeters, and the free dye was determined. The residual trypan blue amounted to 8.4 milligrams, or ten times more than in the case of the knee joint. *This represents a recovery of 12.5 per cent., and an absorption or fixation of 87.5 per cent.* The fixation in this case was, however, many times more obvious than in the knee, as pointed out previously.

No trace of dye was visible in the urine after the operation.

Histological Study

Pieces of tissue were removed from the anterior and posterior walls of the suprapatellar synovial pouch, the infrapatellar synovial fold, and the posterior wall of the knee-joint cavity, in the manner of Kling's technique of systematic dissection of the knee joint. After fixation in 5 per cent. formalin, paraffin sections were prepared in the usual way. Unstained sections, as well as sections counterstained with safranine, were used for locating the dye.

Microscopic examination of these tissues showed that the trypan blue had diffused through, and lightly stained, both the synovial and subsynovial tissues of the knee. The histological picture was much the same throughout the joint, but most vivid at the site of *injection.*

The surface layer or layers of synovial cells, although stained, were generally devoid of dye granules, except for an occasional cell or group of cells. The macrophages of both the synovial and subsynovial layers, however, contained numerous coarse, dark blue

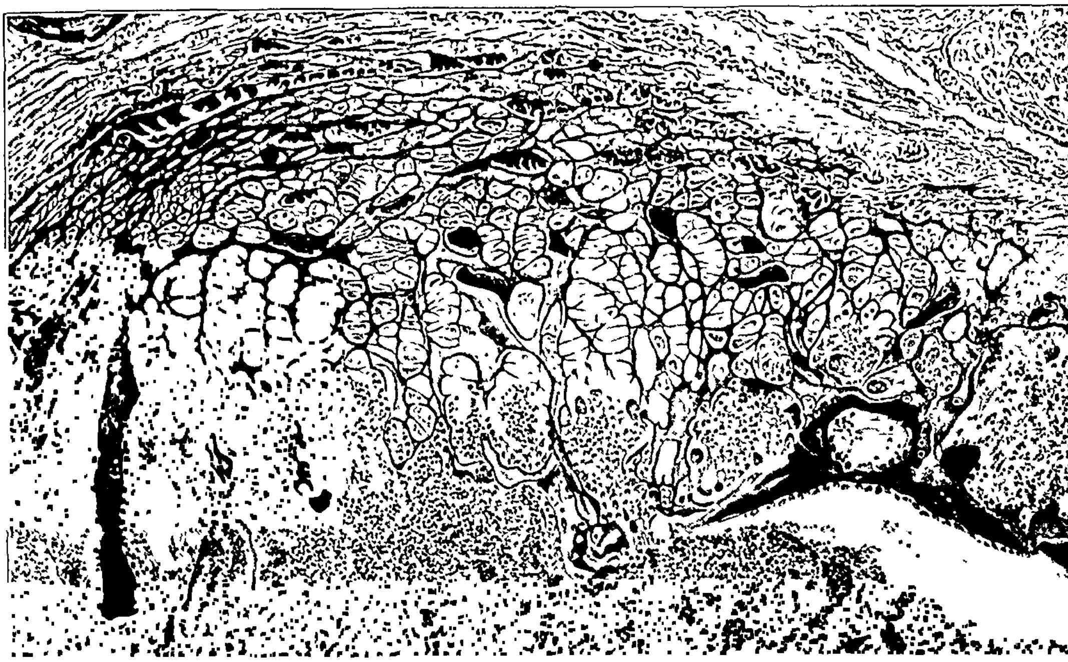

Fig. 5

Osteoma following the intramuscular injection, forty-one days before, of an alcoholic extract of the growth cartilage. Shows newly formed growth cartilage with its perichondrial ring of the ossification groove. Some muscle fibers are confined in the cartilage (× 100). (*Reproduced, by permission, from Bull. Acad. Roy. de Méd. de Belgique, **10**: 529, 1945.*)

Fig. 6

Another region of the same osteoma. The diameter of the bony tube is being enlarged by external apposition and internal absorption (× 100). (*Reproduced, by permission, from Bull. Acad. Roy. de Méd. de Belgique, **10**: 528, 1945.*)

toward the existence in the growth cartilage of an organizer. The question has been pushed another step forward by successful experiments with an alcoholic extract from the growth cartilage.

In a typical case, the cartilaginous epiphyses of two newborn rabbits were cut into chips and extracted in 94 per cent. alcohol. The extract was injected into the thigh muscles of another rabbit. Forty-one days afterward, a large osteoma was found in the thigh. Its

determined colorimetrically, this suggested that the transportation of the dye into the blood stream was principally dependent upon physicochemical factors and the integrity of the circulation. En route, however, the dye had apparently behaved as if within a connective tissue.

In the ankle, on the other hand, the dye presumably had diffused into the articular tissues and was fixed largely by the intercellular matrix. A very small quantity underwent phagocytosis prior to cell death.

The microscopic findings and the marked dye absorption appear, therefore, to confirm for the human joint the assertion that dyes pass rapidly into the synovial intercellular spaces, to be absorbed largely by the capillaries.

SUMMARY

Trypan blue in saline solution was injected into a living normal knee joint, one hour before amputation. During this time 99 per cent. was absorbed, and microscopic examination showed that the dye had stained only lightly the synovial and subsynovial tissues. In general, the synovial cells were devoid of dye granules, but these were visible in the macrophages, the fibroblasts, and the monocytes.

The same amount of trypan blue was injected into the ankle joint after amputation. After five hours, 88 per cent. had been absorbed; but much of this remained fixed in the synovial membrane, and both cells and matrix showed intense staining to a depth of 2 millimeters.

It is concluded that trypan blue is absorbed rapidly from the normal living knee joint, mainly by diffusion into the blood and, to a much less degree, by way of the lymph and by phagocytosis. Circulation to the joint is shown to be an important factor.

NOTE: The authors wish to express their thanks to W. Alan Curry, M.D., for providing the facilities to conduct this experiment, to Professor F. Ronald Hayes for taking kodachrome pictures of the joints, to Miss Barbara Schwartz for preparing the histological sections, and to S. C. Saunders, M.D., for confirming the histological findings.

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MARCH FRACTURES

A Study with Special Reference to Etiological Factors

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Although the medical literature of World War II is replete with articles on march fractures, it seems worth while to report a study, largely etiological in nature, of sixty patients in whom typical march fractures developed under combat conditions in Burma, and who were admitted to the 20th General Hospital in India. The etiology of march fracture has been a matter of controversy for many years, and pertinent data are not only of scientific interest, but may be of vital importance in the event of another extensive military-training program.

During the Central Burma campaign of 1944, the Mars Task Force marched from its training area near Myitkyina, Burma, south toward Bhamo, and then eastward across the mountains to the Burma Road, covering a distance of about 300 miles. Soon after the Mars Task Force left its encampment, a considerable number of patients with typical march fractures began to arrive at hospital installations in the rear. Sixty such casualties were admitted to the 20th General Hospital, and approximately twenty to neighboring installations. The incidence of march fracture in the Mars group was in striking contrast to that of a similar group, Merrill's Marauders, who, eight months earlier, had covered a comparable distance, over like terrain, up the Stilwell Road and into the Hukawng Valley. During the entire Marauders' expedition, only two patients from that command with march fractures were admitted to the 20th General Hospital. Since nearly all their casualties were evacuated to this Hospital, the number approximates the total incidence of the lesion among the Marauders.

In an attempt to explain the unusually large incidence of march fracture in the Mars Task Force, a detailed analysis of the sixty cases admitted to our Hospital was made.

AVERAGE CASE

Based upon averages of the sixty cases, the fracture occurred in a white soldier, twenty-five years old, sixty-nine inches tall, weighing 150 pounds, and carrying a load of fifty-seven pounds. Onset of symptoms was noted on the thirteenth day of the march, after the soldier had traveled 106 miles. Symptoms were essentially identical in all cases of metatarsal fractures, which comprised 93 per cent. of the series. The soldier noticed a sudden and unusual pain in the foot, which was more severe on the dorsal surface over the metatarsal shafts. It differed from any foot pain which he had experienced previously on marching. In half the cases, the soldier could state the exact time of onset; in the other half, the onset could be fixed within six hours. The diagnosis was not, as a rule, made early. After the onset of pain, the soldier continued to march for an average of five days over a distance of thirty-seven miles. During the period of continued marching, swelling developed; and, in most instances, redness appeared on the dorsal surface of the foot. The pain progressively increased until walking was no longer possible, and evacuation was necessary.

All patients were evacuated through one of the forward medical installations, where the correct diagnosis was usually made, and a plaster boot was applied to the affected foot. At the time of examination in this Hospital, every patient showed some degree of swelling over the dorsal surface of the foot, usually greatest over the distal third of the metatarsals. A universal finding was spot tenderness at the site of fracture; so that, in almost every case, the patient could place his finger tip directly on the fracture. The history and findings on examination were so characteristic that, in the earlier stages, diagnosis could often

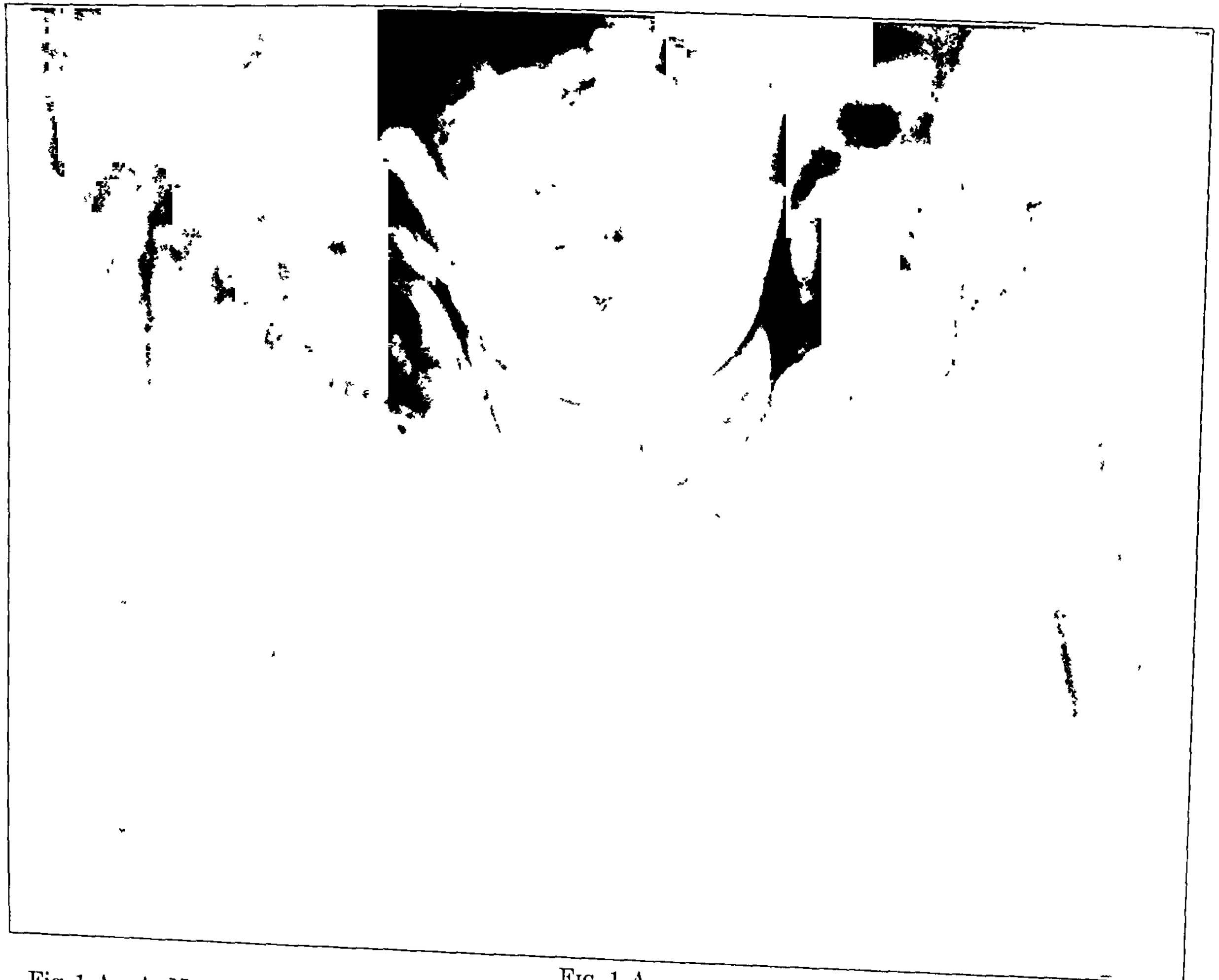

Fig. 1-A

Fig. 1-B

Fig. 1-A: A. N., aged sixty-seven. Old unreduced fracture of the right hip. Recent fracture of the left hip. The high displacement of the shaft, the complete absorption of the neck, and the necrosis of the head are contra-indications to any operation on the right hip, except an arthrodesis. The left hip was nailed.
Fig. 1-B: Shows good reduction of the fracture of the left hip and position of the Smith-Petersen nail.

TABLE II

FACTORS OF ETIOLOGICAL SIGNIFICANCE IN SIXTY PATIENTS WITH MARCH FRACTURE

	MARCH FRACTURE GROUP		CONTROL GROUP	
	Number	*Per Cent.*	*Number*	*Per Cent.*
Previous training				
Adequate	11	18	31	51
Inadequate	49	82	29	49
Total	60	100	60	100
History of previous foot complaints	15	25	10	17
Pes planus	22	37	4	7
Ankle valgus	25	42	4	7

hikes per week for the three weeks immediately prior to the march was arbitrarily set up as a standard for evaluating adequacy of foot conditioning. It was found that 51 per cent. of the control group had met this quite reasonable standard, whereas it was met by only 18 per cent. of those in whom fractures developed. The control group also had superior conditioning during their period of training in the Zone of the Interior, although these benefits might well have been vitiated during the sea voyage. Further data concerning the value of training in prevention of march fractures are provided by a comparison of the incidence of fractures in the two American regiments in the Mars Task Force. One regiment had been required to march to and from field manoeuvres and had had more rigorous marching training than the other regiment. Both had approximately the same number of men and made roughly identical marches. The incidence of march fracture was five times as great in the regiment with the lighter training program.

Intensive conditioning very likely explains the low incidence of fracture in the Merrill Marauders group, mentioned previously. Unlike the soldiers of the Mars Task Force, Merrill's Marauders had engaged in previous campaigns requiring vigorous marching and, of more importance, had had superb conditioning during the weeks immediately preceding the march.

It is interesting that a march fracture was never encountered in a Chinese soldier in the 20th General Hospital, although large numbers of Chinese casualties were admitted from units which made essentially the same march as the Mars Task Force. It is obvious that many diverse factors play a part in this discrepancy. Nevertheless, the fact that Chinese soldiers were more accustomed to strenuous foot activity than Americans is further evidence that inadequate conditioning is an important factor in the production of march fracture.

The conclusion was reached that a march fracture occurs in a structurally inadequate and improperly conditioned foot as a result of functional overloading. It is significant that a much larger percentage of the fracture group showed pes planus and ankle valgus. It is possible that some of these static disorders were not present before the onset of the march, but were produced by overloading an inadequately conditioned foot.

Much has been written concerning atavistic foot structure in the production of march fracture. All the roentgenograms of the fracture group were studied with this in mind. For comparison, sixty roentgenograms of feet, which had been made for reasons other than march fracture, were selected at random in the Department of Radiology. Admittedly this was not a perfect control group, but scarcity of film made it impossible to examine that number of clinically normal asymptomatic feet, or to examine the sixty patients of the control group. In studying these roentgenograms, we adopted a short first metatarsal as the primary criterion of abnormal foot architecture. A line was drawn across the film at the distal margin of the first metatarsal, at right angles to the axis of the foot. The distance of extension of the second metatarsal beyond this line was expressed as "plus" in millimeters. If the distal end of the second metatarsal fell short of the line, this distance was

FIG. 2

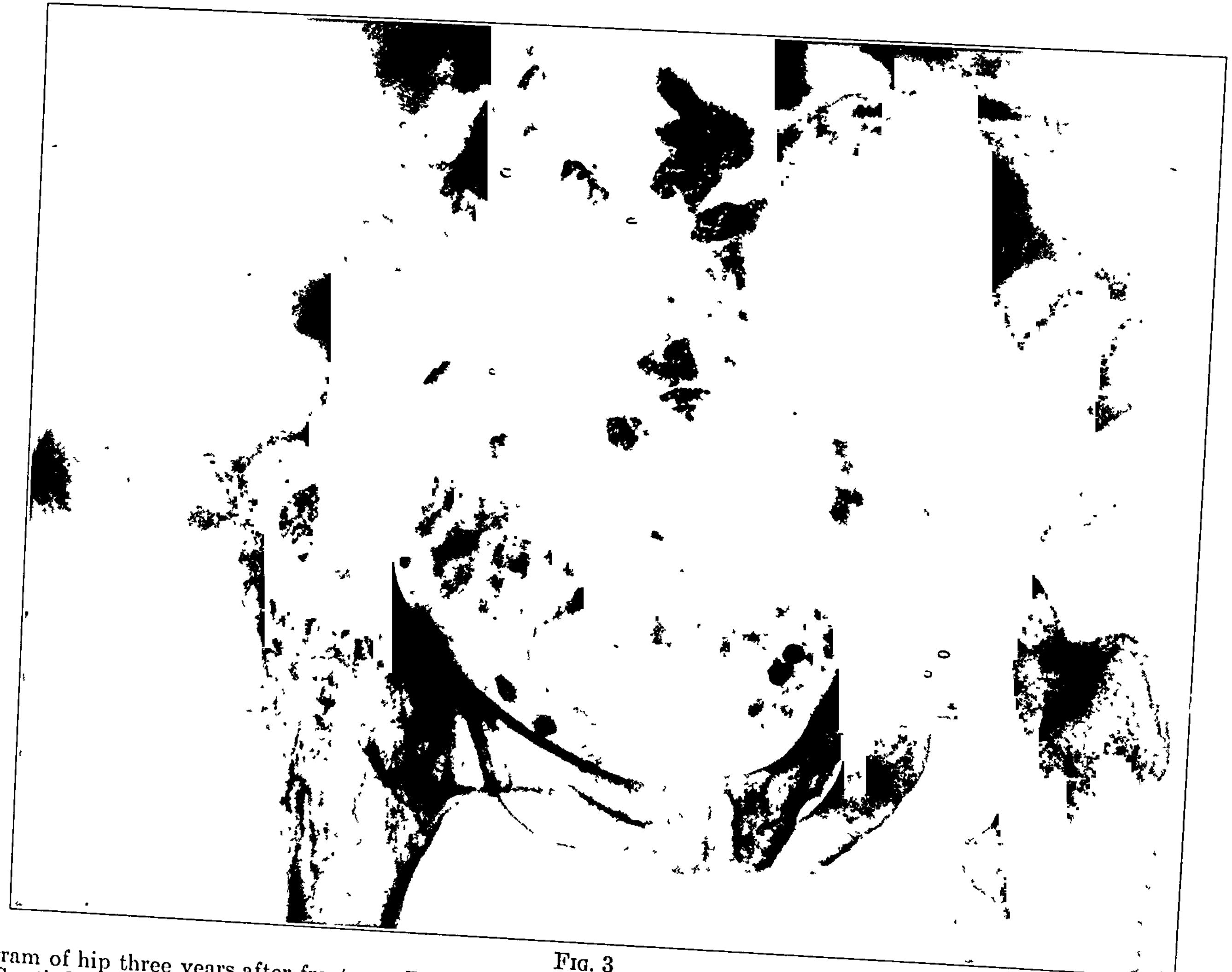

FIG. 3

FIG. 2: E. M. S., aged fifty-three. Roentgenogram of hip three years after fracture. Patient had had complete union at the site of the fracture, following practically perfect reduction and the use of the Smith-Petersen nail. Two years after operation the patient began to have pain in her hip. Roentgenograms made at that time showed beginning necrosis of the upper portion of the head of the femur. Present roentgenogram shows marked necrosis. She has been able to walk only with crutches.

FIG. 3: F. C. Roentgenogram made seventeen years after fusion of the hip for fracture of the neck of the femur. Hip was fused because of very rapid absorption of the neck of the femur occurring within three months of the fracture. During the intervening years, the patient has supported herself by doing fairly hard work. The functional result has been extremely satisfactory to the patient.

ABSORPTION OF TRYPAN BLUE FROM THE HUMAN KNEE JOINT

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Little information is available on the rate of absorption of chemical substances from normal *human* joints and on the pathways involved. Most experiments on the permeability of synovial membrane have been conducted on animals. Those performed on man have been largely on diseased joints, and there appear to be few records of actual experiments on normal human joints.

The mode of transfer of trypan blue from the joint cavity to the blood stream has been carefully studied in animals by a number of workers, including Rynearson, Key, Adkins and Davies, and Clark. As far as such diffusible dyes are concerned, the consensus is that they are largely absorbed by capillaries and, to a lesser extent, by lymphatics[2].

Dyes, such as trypan blue, have not been used in the study of these mechanisms in man. It seemed desirable, therefore, to test the direct applicability of some of these assertions to the living human joint, and at the same time to attempt a quantitative determination of the absorption. Trypan blue was selected because it is a readily soluble dye, free from local irritative and general toxic effects.

PROCEDURE

The case selected for study was that of a young male, aged twenty-three years, who was forced to lose his left lower limb because of a growth, involving the proximal part of the thigh on the lateral aspect. The pathologist subsequently reported that the growth was a diffuse endothelial myeloma or Ewing's tumor, involving the upper third of the left femur.

It was decided to carry out an intra-articular injection of trypan blue into the knee joint prior to amputation, to submit the joint to histological examination after operation, and to determine the degree of absorption colorimetrically.

The quantity of synovial fluid in healthy human joints has been found in amounts varying from 0.13 to 3.5 cubic centimeters in 124 knees, examined immediately after death by Ropes, Rossmeisl, and Bauer, while the cubic capacity is given as between 60 and 300 cubic centimeters[2]. The injection of a small volume of solution could, therefore, produce no undue distension of the knee joint.

A solution of trypan blue (3.00 grams per 100 cubic centimeters of 0.9 per cent. sodium chloride, reagent grade for biological work) was prepared and sterilized in the autoclave. Three cubic centimeters of this solution was then placed in sterile ampoules. A solution for colorimetric estimation of the trypan blue present was made by diluting 1 cubic centimeter to 100 cubic centimeters. A standard solution, containing exactly 0.100 gram of trypan blue, was prepared in 1 per cent. sodium chloride, from which other standards were made by dilution. This permitted the determination that the fluid injected contained 33.8 milligrams of trypan blue per cubic centimeter.

This solution of trypan blue (2 cubic centimeters) was injected, under local anaesthesia, into the superolateral aspect of the suprapatellar synovial pouch at 2:34 P.M. on the afternoon of the operation. The knee was passively flexed about 45 degrees and then extended, about six times, in order to disperse the dye throughout the joint. The injection was attended by no local or systemic effects.

A high-thigh amputation was begun about an hour later, at 3:40 P.M. The femoral vessels were ligated at 3:50 P.M., and the vessels on the back of the thigh soon after. The extremity was removed at 4:40 P.M.

THE WHITMAN RECONSTRUCTION OPERATION FOR COMPLICATIONS OF FRACTURE OF THE NECK OF THE FEMUR *

BY ARTHUR KRIDA, M.D., NEW YORK, N. Y.

INTRODUCTION

The outcome of a fracture of the neck of the femur may fall into one of the following categories:

1. Death of the patient;
2. Non-union without aseptic necrosis of the head;
3. Non-union with aseptic necrosis of the head;
4. Non-union with absorption of the neck;
5. Non-union after pinning, with some degree of infection;
6. Union of the fracture and restoration of function;
7. Union with late necrosis of the head and secondary osteo-arthritis;
8. Union with late necrosis of the head and the development of an aseptic sequestrum;
9. Union with necrosis of the head and gradual complete regeneration of the head, with restitution of function.

INDICATIONS FOR OPERATIVE TREATMENT

The failure of primary treatment of this fracture frequently indicates the employment of reconstructive procedures.

Whether or not any operative treatment should be undertaken depends upon considerations applicable to the individual in question. Aged individuals in poor condition are not proper subjects for operative treatment.

The ordinary group consists of people in fair general condition, whose locomotor ability has been severely curtailed, and who suffer a great deal of pain.

Sometimes when there is a question as to the advisability of operation, consideration of the patient's social and economic environment is more important than the pathological condition. Since increase in physical capacity and relief of pain are objects of comparative value, and since all reconstructive procedures on the hip joint entail a good deal of fortitude and cooperation on the part of the patient, the question of operative interference has frequently to be answered on grounds other than those of the actual gross pathological picture.

General indications for operative treatment may be found in all the subdivisions of the subject listed in the Introduction, with the exceptions of 1, 6, and 9. It may be stated here that operations designed to secure union of the head and neck fragments are ordinarily disappointing in non-union with aseptic necrosis of the head (3), and non-union with absorption of the neck (4). This applies not only to pinning and bone-grafting operations, but also to osteotomies.

Operations dealing with union with late necrosis of the head and secondary osteo-arthritis are of the type usually practised for ordinary osteo-arthritis of other origin, and will not be dealt with specifically.

THE WHITMAN OPERATION

Indications

General indications for this operation may be found in non-union with aseptic necrosis of the head (3); non-union with absorption of the neck (4); non-union after pinning with

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1946.

granules of dye. Many subsynovial fibroblasts also contained dye deposits, lying close to the nucleus or scattered about the cytoplasm. There was frequent evidence of the staining of intravascular blood cells, and a number of granule-laden monocytes were observed. Few polymorphonuclear cells were present.

Sections of a popliteal lymph node showed a few blue-stained macrophages, but no other significant changes. Inguinal lymph nodes were, unfortunately, unobtainable at the operation.

Similarly prepared and stained sections of the synovial membrane lining the anterior and posterior ligaments of the ankle showed marked staining of the synovial and subsynovial cells and cell processes to a depth of about 2 millimeters. Again, with a few exceptions, no dye granules were observed within the synovial surface cells. Macrophages, placed synovially and subsynovially, contained dye granules, as did some fibroblasts; but in neither case were they so striking as those seen in similar cells in the knee.

In view of Burman's work on the effect of dyes on joint cartilage, hand-cut sections were made of the articular cartilage; *that of the knee showed superficial staining, while the ankle showed intense staining of the cells and matrix to a depth of five or six rows of cartilage cells.*

DISCUSSION

Trypan blue was selected because it is a common vital stain, without local irritative or general toxic effects when in low concentration in saline solution. It is an acid azo dye, similar to Congo red, with a molecular weight of 960. This type of dye has been shown by Höber to be readily diffusible. The size of particle in aqueous solution has not been determined, but from the observation of Engel on the rate of diffusion through gelatin gel, and by comparison with Congo red from the determination of Gordon and Chambers, it must be about 1 millimicron.

Synovial membrane is a layer of modified connective tissue of appreciable thickness. Soluble substances passing from the joint cavity to the blood stream must traverse its tissue spaces and fluids by diffusion or selective absorption, before reaching the blood or lymphatic capillaries. A varying period of detention within it may therefore be expected, according to the substance considered, the reaction it evokes, and the initial condition of the tissue.

We are here comparing the passage of an innocuous soluble substance, under similar conditions, from the knee joint and from the ankle joint, except that in the first instance there was active circulation to the joint for one hour and in the latter instance there was not. The importance of circulation is established both chemically, macroscopically, and microscopically in this case.

Adkins and Davies have concluded, from numerous experiments with rabbits, that substances in true or molecular dispersion are absorbed mainly by diffusion into the blood stream, while substances in a state of colloidal dispersion are absorbed both by the lymphatics and the blood in the course of one to two hours. In fine suspension, there is slow removal by the lymphatics only, or none at all. Adkins and Davies stress absorption as being predominantly a physical process, independent of synovial-cell activity. In rabbits, trypan blue was found to occupy an intermediate position between the molecular and colloidal states. The authors' evidence in the human would support this conclusion.

The spread of dyes through living synovial tissue has never been observed microscopically. Parsons and McMaster showed, however, that dye moved either along or between the connective-tissue fibers, and was influenced by such factors as oedema and vessel pulsation. King showed further that trypan blue is primarily fixed by the intercellular connective tissue.

The histological picture in the knee was not one of marked phagocytosis or cellular activity. Coupled with the marked and rapid absorption (99 per cent.) of the dye, as

FIG. 1-A FIG. 1-B

Fig. 1-A: Typical ununited fracture of the hip with absorption of the neck.
Fig. 1-B: The same case about eight months following the Whitman operation.

General Physical Capacity

The difference between crutches or wheel chair and comparatively comfortable ambulation without appliances, other than the occasional use of a cane, does not need emphasis. The ideal result was obtained in a farm laborer who had had an unsuccessful pinning with some degree of infection. He returned to his arduous labors. The intermediate type of result is exemplified by the elderly woman who was obliged to do her housework, and who was enabled to perform such work with a reasonable degree of satisfaction. The failure is illustrated by the individual who does not possess the requisite degree of cooperative endeavor to rehabilitate himself thoroughly, or who is denied the opportunity of skilled and sometimes prolonged postoperative care.

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ARTHRODESIS OF THE HIP FOR UNUNITED FRACTURES *

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In general, union and non-union of fractures of the neck of the femur are but two phases of the same problem. Of course, the goal of every surgeon is to find a uniform and universally successful treatment of fractures, so that the problem of non-union becomes non-existent. The incidence of non-union has been materially reduced in recent years, by a more meticulous application of the old principles of complete reduction and absolute fixation. Much of the present literature deals with methods of internal fixation. The writer is not aware that any surgeon can make substantiated claim to 100 per cent. successful bony union by any method of treatment. Add the failures of good treatment to the vast number of cases of non-union resulting from poor treatment, and it is apparent that the treatment of non-union merits our attention. We must bear in mind, also, those not infrequent cases of necrosis of the head of the femur, that become evident after complete bony union has taken place. Patients with this condition may be almost as disabled as if bony union had never occurred.

It is apparent to the surgeon, therefore, that some factor in the repair of fracture of the neck of the femur and in the permanent restoration of normal function of the hip joint is at present beyond our control. We explain this by saying that aseptic necrosis of the neck and the head of the femur occurs, because there is incomplete restoration of blood supply to the affected bone. While this is probably true as far as it goes, it does not explain why, with the use of the same method of treatment, it occurs in one individual and not in another. If it is not due to variations in the destructive nature of the local injury, is it due to differences in the regenerative powers of the individual? This subject merits intensive study; because, if we could know what patients are doomed from the moment of fracture to non-union or to necrosis of the head following union, we could save them months or years of inactivity, disability, and pain.

If non-union exists, which operation among several should the surgeon elect to restore painless function of the hip? What are the indications and the contra-indications for each of them? If any one of the standard procedures is proved to give a perfect result in all cases, it should undoubtedly be the operation of choice.

Arthrodesis of the hip is indicated when other operations have failed, and it should be used primarily when there are contra-indications to other operations. If it is the last resort for some patients, why should it not have been for them the first resort?

Contra-Indications for Operations to Secure Union

1. Rapid absorption of the neck of the femur after the fracture;
2. Absorption of a large portion of the neck of the femur, including its distal portion;
3. Aseptic necrosis of the head of the femur;
4. Chronic degenerative arthritis.

Contra-Indications for Arthroplasty or Reconstructive Operations

1. Complete or almost complete absorption of the neck of the femur;
2. Degenerative arthritis;
3. Rigid or painful lumbar spine. Abduction of the femur when bearing weight is necessary to keep the upper end of the femur in the acetabulum. This produces tilting of the pelvis, and a lateral bending of the lumbar spine.

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united fracture of the neck of the femur was performed in 1943, and since then eight patients with this pathological condition have undergone this operation. It is the author's purpose to present the results obtained in these patients.

OPERATIVE PROCEDURE

The various steps in the operation are more easily shown in the accompanying illustrations than by a textual description.

1. The exposure is obtained by Smith-Petersen's incision with the portion distal to the anterior superior spine of the ilium curving outward and posteriorly over the lateral surface of the tensor fasciae latae near its insertion. The upper half of the lateral skin and muscle flap which includes the anterior portions of the glutaeus medius and glutaeus minimus, as well as the origin of the tensor fasciae latae, are stripped subperiosteally from the lateral surface of the ilium and from the anterior superior iliac spine. The space between the tensor fasciae latae and the rectus fundus is then found and separated, and the entire lateral flap, including the previously mentioned portions of these muscles, is retracted laterally. When additional exposure of the medial portion of the hip joint is required, the iliopsoas may be stripped from the inside of the iliac crest as well as the insertion of the sartorius, so that these muscles may be retracted medially.

2. Next, in order to expose the trochanteric end of the femur, the distal end of the tensor fasciae latae is divided transversely in the line of the distal end of the laterally curving incision. This permits this muscle to be retracted from the underlying upper portion of the vastus lateralis, which covers the upper end of the femoral shaft as far as the tip of the greater trochanter. The lateral surface of the greater trochanter is now visualized.

3. An incision is next made in the upper lateral portion of the vastus lateralis in the axis of the femur, and the fibers are stripped subperiosteally, exposing the upper end of

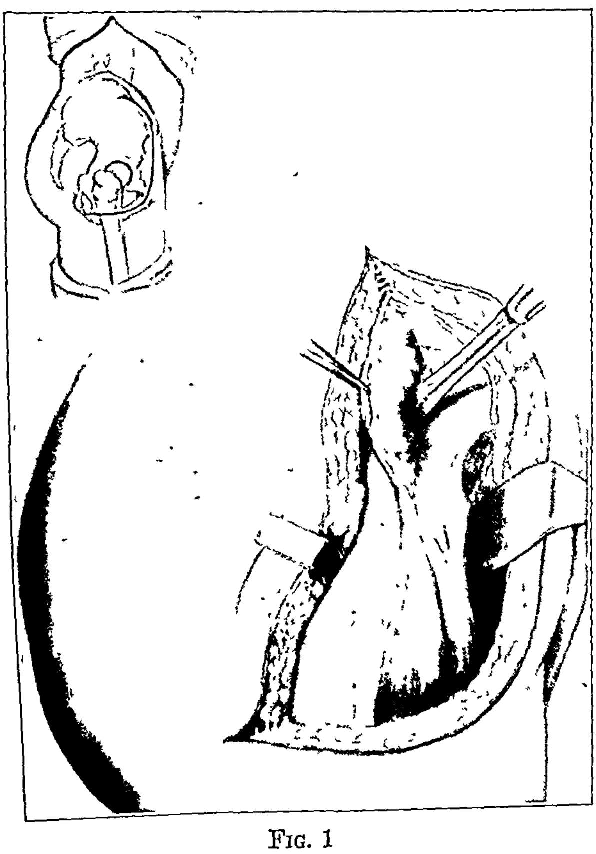

Fig. 1

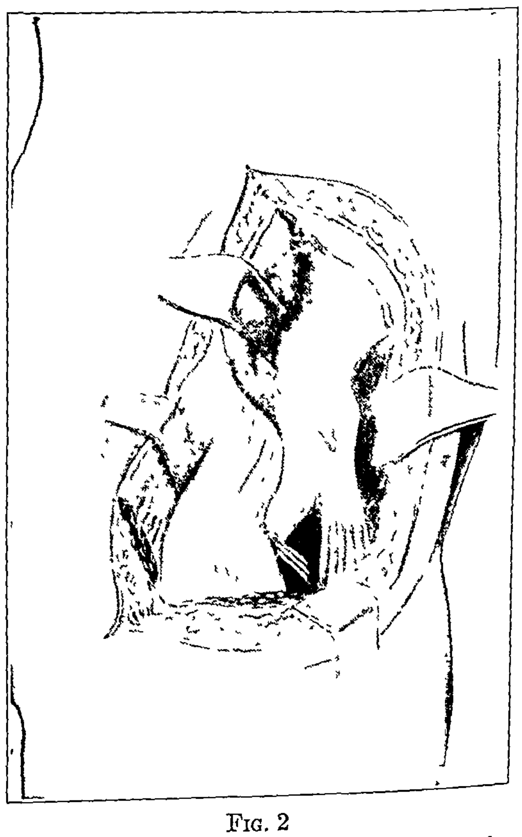

Fig. 2

Fig. 1: Shows Smith-Petersen's incision with distal end curving backward over insertion of the tensor fasciae femoris.

Fig. 2: Shows the distal end of tensor muscle divided and retracted backward, in order to expose the upper end of the femur.

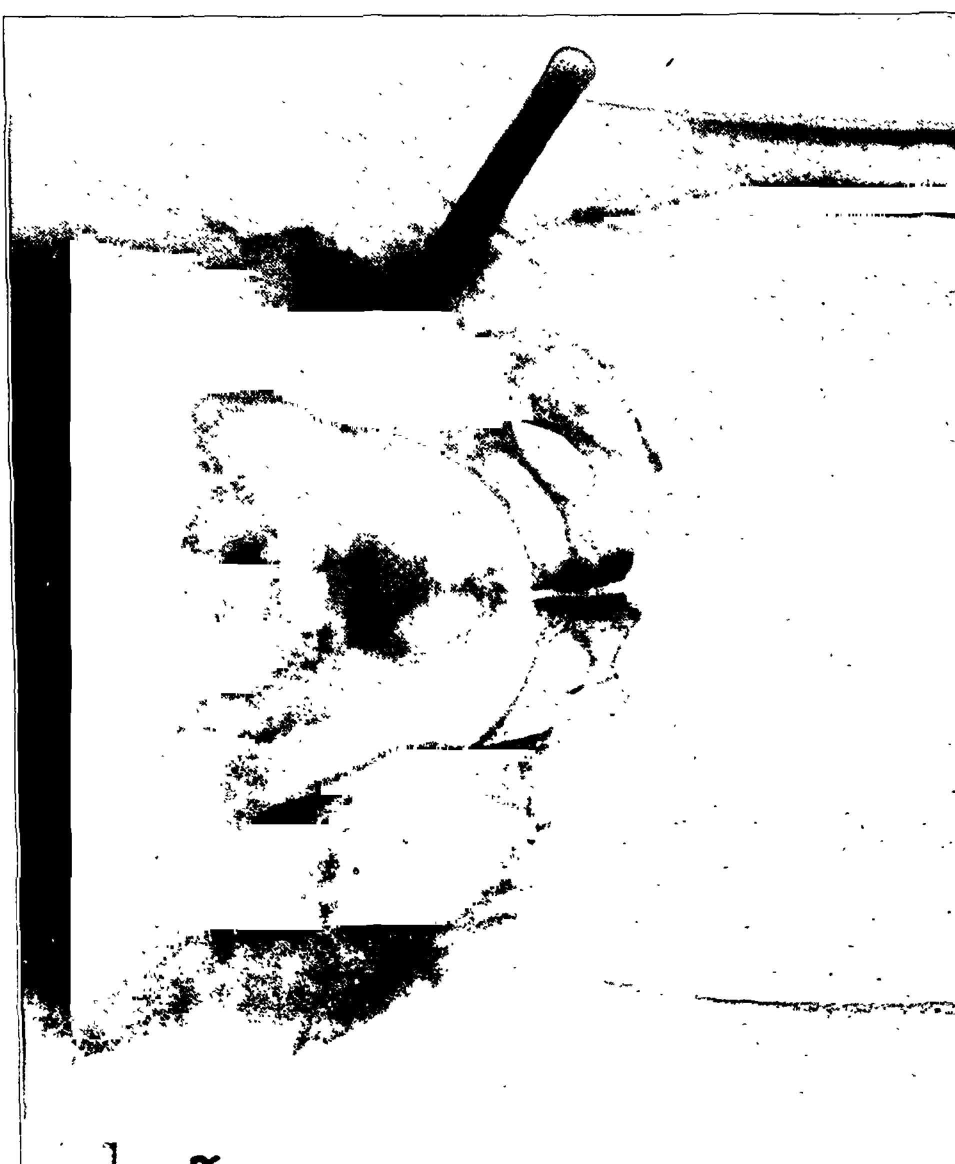

Fig. 1-C

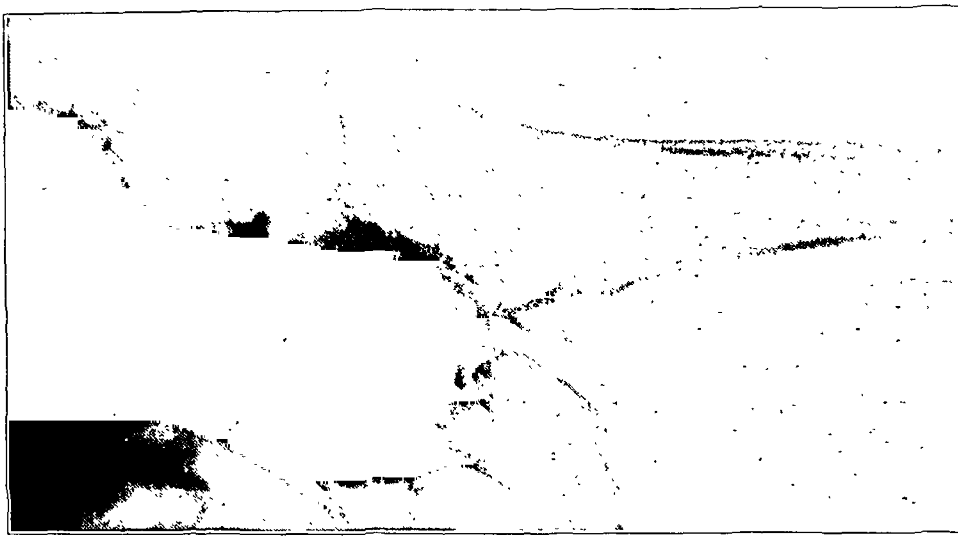

Fig. 1-D

Fig. 1-C: Shows absorption of the neck of the femur with non-union and protrusion of the nail. Because of the absence of necrosis of the head, and because of the old non-union of the right hip, subtrochanteric transverse osteotomy was considered to be the best operative procedure.

Fig. 1-D: Shows left hip subsequent to the osteotomy. Following operation on the left hip, the patient had good function until his death about a year later, due to another cause.

entire trochanter by the use of a blunt instrument, in order to detach a fragment of proper size. This fragment should be as small as possible in order not to seriously reduce the substance of the trochanter, which must be saved for the construction of the new head, and also because a large fragment generally proves awkward for later transplantation to the femoral shaft.

4. The separation of the trochanteric fragment permits better exposure, and facilitates the next step, which is removal of the fragment of the head of the femur. The pseudarthrosis is first identified and divided, which allows the femoral shaft to be externally rotated, and exposes the distal surface of the head fragment. The head is now identified by trimming away fibrous tissue remaining from the pseudarthrosis and the remainder of the anterior capsular ligament. The removal of the head fragment is always difficult, partly because the operator cannot grasp it properly with an instrument, and also because of the fibrous hypertrophy of the attached capsular ligaments. Doubly curved gouges may be introduced between the articular surfaces to act as levers to dislocate the head, and they also help to identify the ligamentous attachments which must be divided. With a little patience and care, the head can be freed and removed in its entirety.

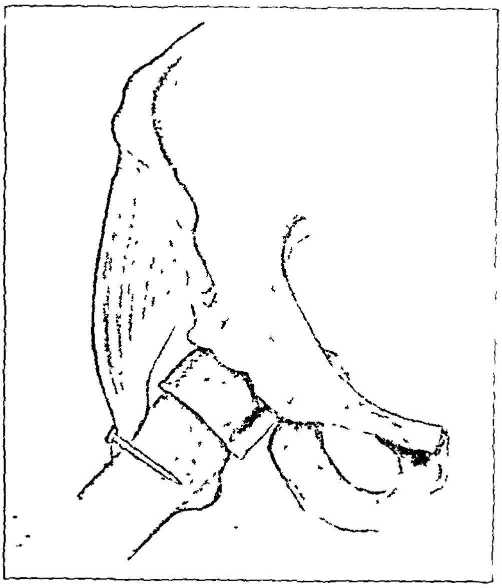

FIG. 7

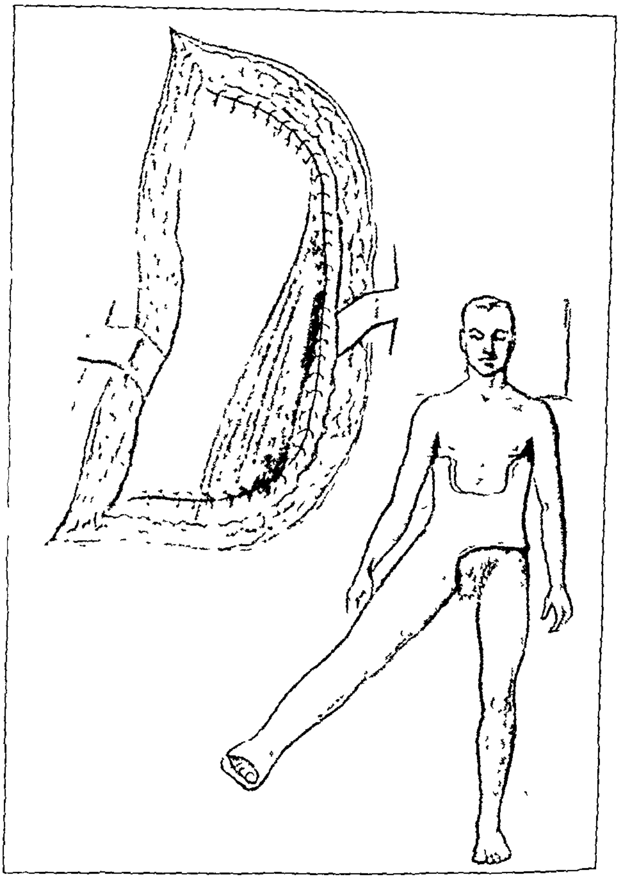

FIG. 8

Fig. 7: Shows the reattachment of the greater trochanter.
Fig. 8: Shows the wound closure and the plaster-of-Paris fixation with hip in abduction.

5. The next step is the mobilization and remodeling of the upper end of the femoral shaft. This is best accomplished by seizing the shaft below the greater trochanter, where the vastus lateralis has been previously stripped away with a heavy, large-jawed Lane forceps. While an assistant manipulates the distal portion of the extremity, the upper end of the shaft is pulled out of the wound with the forceps, and the posterior short external rotator muscles are divided close to their insertion to the femur, including both obturator muscles, the gemelli, and a part of the quadratus femoris. The upper end of the femur is thus completely mobilized and brought out of the wound. The trochanteric end is then remodeled with the aid of sharp, doubly-curved gouges, and rounded off with the concave reamer or rasp if necessary, so that it fits smoothly into the selected size of vitallium cup or mold.

Contra-Indications for the Types of Osteotomies which Produce Abduction of the Femur

1. Gross necrosis of the head of the femur;
2. Degenerative arthritis;
3. Complete absorption of the neck of the femur and marked upward displacement of the shaft;
4. Rigid and painful backs.

Methods of Choice

Transverse intertrochanteric osteotomy, with displacement of the shaft inward beneath the head of the femur, is frequently used at the present time. In recent years, I have done this operation more often than any other. Not all patients have had good and painless function, and I do not know the end results in all cases. The theoretical contra-indications would be arthritis of the hip, necrosis and softening of the head, and high displacement of the shaft of the femur.

Arthrodesis of the hip gives stability and freedom from pain. Its disadvantage is the consequent lack of mobility of the hip joint. The patient is unable to bend forward to lace the shoe on the affected extremity. Unless the hip is fused in a position of moderate flexion of about 30 degrees, there is difficulty in sitting comfortably in a chair, and low-back pain may develop. Furthermore, the extremity should not be abducted, but should be in the longitudinal line of the body, enabling the patient to walk better, and preventing abnormal lateral strain from being thrown on the lumbar spine.

END RESULTS

Including only those cases which have been under observation for from two to seventeen years, solid fusion occurred in 60 per cent. and non-fusion in 40 per cent. The patients whose hips were fused had no disability in standing, in walking, or in doing their usual work. They considered inability to lace the shoe a slight inconvenience, compared to the pain and instability which had been present preceding operation.

All of the patients whose hips were not fused were free of pain, and had stable hips. One has worked as a mail carrier for seventeen years since his operation. He now has 50 degrees of motion in flexion, and about 15 degrees in abduction. There is a negative Trendelenburg sign. This man has never lost a day at work on account of his hip, and is still on active duty, walking from thirteen to fourteen miles a day. In such cases the femur remained in the acetabulum without abduction, because at the time of operation the roof of the acetabulum was excavated and made dome-shaped, so that the end of the femur fitted into it, and remained securely in place without abduction.

CONCLUSIONS

1. Arthrodesis is one method to be considered in treating cases of non-union of the hip. It should also be considered in cases of painful necrosis of the head following union.
2. It should be the method of choice, if it can be determined that there are contra-indications to other operative procedures.
3. It is the last resort when other operations have failed.
4. In the writer's experience, bony ankylosis has occurred in only 60 per cent. of the patients operated upon, but the remaining 40 per cent. have had stable and useful hips, and have not complained of pain.
5. Ankylosis of the hip, with the extremity in proper position for weight-bearing and locomotion, enables the patient to resume an active life, and the absence of motion constitutes a comparatively slight disability.

REFERENCES

GILL, A. BRUCE: Treatment of Fractures of the Neck of the Femur. Ann. Surg., 96: 1–16, 1932.
——— Arthrodesis for Ununited Fracture of the Neck of the Femur. J. Bone and Joint Surg., 21: 710–714, July 1939.

generally necessary for a period of from four to six weeks. Generally this is most conveniently and comfortably accomplished by the application of a plaster-of-Paris spica.

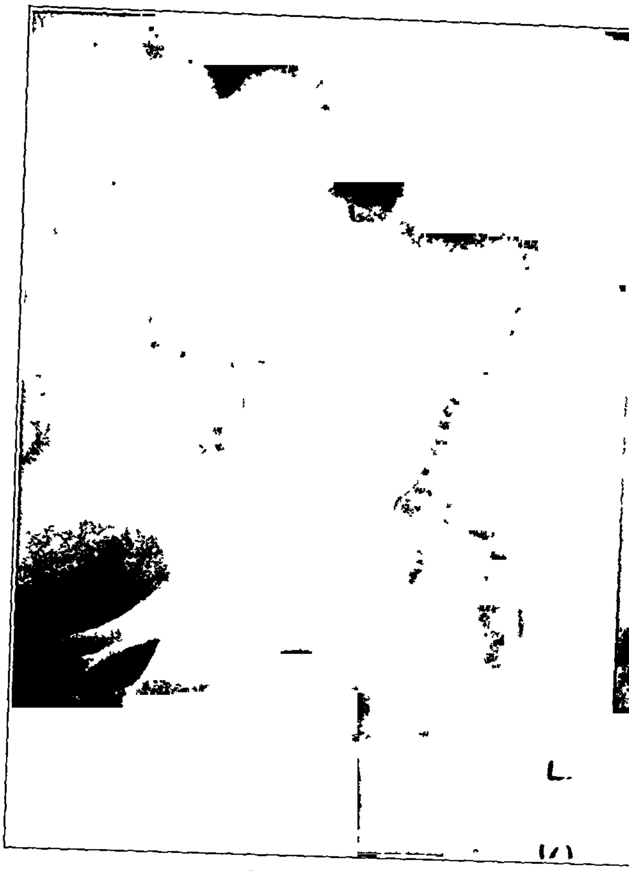

Fig 9-B

Fig. 9-C

Fig. 9-D

Fig 9-E

Roentgenograms at various stages during the course of treatment

Figs. 9-D and 9-E were made four years after the arthroplasty. Patient leads a normal life and has normal control and motion of the hip.

some degree of infection (5); and union with late necrosis of the head and secondary osteo-arthritis (7).

Specific indications for the removal of the head of the femur are to be found in those conditions where the removal offers the only obvious and reasonable solution of the pathological problem. Thus non-union with aseptic necrosis of the head (3); non-union after pinning, with some degree of infection (5); and union with late necrosis of the head and the development of an aseptic sequestrum (8) may all be considered as indications for removal. Non-union with absorption of the neck is a border-line condition, which may be treated by osteotomy, but which on the whole is more satisfactorily dealt with by the Whitman operation.

The Technique of the Whitman Operation

The principles were described by Whitman in 1921[1]. An anterolateral incision is made from the anterior superior spine of the ilium downward to four inches below the tip of the greater trochanter, and then extended posteriorly to well behind the shaft of the femur, through the fascia lata in this region. The hip-joint capsule is exposed between the tensor fasciae femoris and the glutaeus medius. The trochanter is defined, and is then osteotomized in line with the neck of the femur. The capsule is opened, and the head of the femur is removed. The trochanteric fragment is mobilized, and, after insertion of the neck fragment into the acetabulum, it is transplanted subperiosteally upon the lateral aspect of the femur, well below its usual position. A plaster-of-Paris spica is applied with the extremity in abduction.

Postoperative Treatment

The period of splintage in plaster advocated by Whitman has been found to be too long. The trochanter unites readily. The plaster is removed after three weeks, and a regimen of active and passive motion is instituted, together with heat and massage. The patient is allowed to become ambulatory, when he has demonstrated a reasonable degree of muscular control of the limb, which is ordinarily accomplished in about six weeks.

EVALUATION OF RESULTS

This paper is based upon twenty Whitman operations performed during 1934–1944. These cases may be grouped as follows:

Non-union with absorption of the neck	14
Non-union after pinning, with some degree of infection (1 major, 1 minor, both after primary pinnings performed elsewhere)	2
Late osteo-arthritis	2
Union with late necrosis of the head and the development of an aseptic sequestrum	2
	20

Relief of Pain

One of the principal objects for performing the operation is the relief of pain. Inasmuch as four patients failed to secure such relief, they do not warrant classification as satisfactory results.

Range of Motion

The range of motion obtained in these cases was exceedingly variable. No patient obtained more than 90 degrees, and the few who obtained anything approximating it presented some degree of instability. Thus one patient who exhibited a range of 90 degrees (aseptic sequestrum) had complete relief from pain, but had a pronounced limp. The occasional patient who exhibited the most pronounced degree of restriction of motion (from 20 to 30 degrees) had the greatest stability, and the greatest relief from pain.

attached to a vertical frame, so that the patient may flex the hip and knee at frequent intervals during the day. The patient is also sent to the warm-water pool daily for under-water exercises, performed with the assistance of a physiotherapist. Active exercises are done in bed with the foot supported on a roller skate. The patient is also encouraged to sit up in a chair.

Weight-bearing is not generally permitted until the end of eight to ten weeks after operation, and then only with the assistance of crutches. The crutches are discarded in favor of a cane only when there is complete absence of pain as well as good muscular control of the hip.

Complications

The chief complication that must be guarded against with this type of operation is luxation. This cannot occur when the hip is in abduction, but the stability of the hip decreases as the hip is brought down to the neutral position, and there is instability, as well as risk of dislocation in the position of adduction. This risk is greatest during the first two weeks after the plaster is removed, and during this time it is well to prevent the hip from assuming an adducted position. This may be accomplished by placing sandbags at the inner side of the leg, and by instructing the patient as to the posture of the limb which should be maintained.

Ultimate stability of the hip depends upon the development of cicatricial tissue at the lateral border of the new joint, and at the end of eight weeks this is generally quite secure.

Luxation occurred in two of the writer's cases, but was quickly detected and readily overcome by the simple manoeuvre of abducting the hip, in one case with the patient under an anaesthetic. In both cases it occurred within the first two weeks after the removal of the plaster. In spite of this complication, both patients made a good recovery and obtained good functional results. The reduction was maintained by the use of short plasters applied to both legs from the toes to below the knees and joined together by a bar to maintain abduction. They were made removable so that the hip could be freed for exercise each day. After treatment by this method for periods of from four to eight weeks, the patients were allowed to begin walking with crutches. In both cases eventual stabilization of the hip was aided by calcification of the soft tissues at the lateral border of the acetabulum, which resulted in the formation of a bony shelf. This suggests the possibility of forestalling nature's method by implanting a bony shelf at the time of operation when the hip seems unusually unstable.

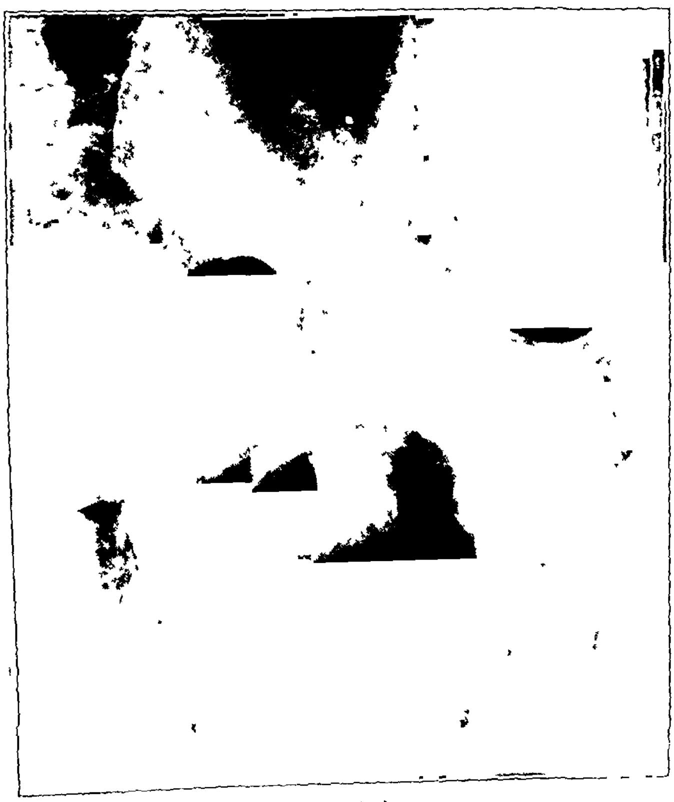

Fig. 11-A
Case 3. M. H. March 15, 1945.

RESULTS

It seems unjustifiable to take the space to report the individual case histories of the nine patients with ununited fractures of the neck of the femur upon whom the operation of trochanteric arthroplasty was

TROCHANTERIC ARTHROPLASTY IN THE TREATMENT OF UNUNITED FRACTURES OF THE NECK OF THE FEMUR *

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The term trochanteric arthroplasty is used in this article to designate an operation on the hip in which the head and the neck of the femur are removed, and the trochanteric end of the shaft of the femur is reshaped, covered with a vitallium cup or mold, and then placed in the acetabulum. As a preliminary step, the tip of the greater trochanter is cut away from the rest of the femur, the attachments of the glutaeus medius and glutaeus minimus being preserved. This fragment is later transplanted to the shaft of the femur distal to the greater trochanter.

This operation is a development of the ideas of Whitman, Colonna, and Smith-Petersen.

Whitman believed that, in ununited fractures of the neck of the femur, the proximal fragment was often necrotic from loss of blood supply, and that the chances of securing bony union by any surgical procedure were small, and the chances of obtaining satisfactory function even less. As a solution of the problem, he devised the reconstruction operation, in which he removed the head fragment and inserted the remnant of the neck of the femur into the acetabulum. Since the neck was often very short and caused the greater trochanter to impinge against the lateral border of the acetabulum, he removed the projecting tip with its attached muscles and reimplanted this bone fragment more distally on the femoral shaft, thus prolonging the neck of the femur and preserving the function of the iliofemoral muscles. He immobilized the hip in a plaster-of-Paris spica for a period of from four to six weeks with the limb in a position of abduction, and at the end of this time started exercises and physical therapy.

Colonna later described a reconstruction operation for ununited fractures of the neck of the femur, in which the head of the femur was removed and the muscle insertions to the greater trochanter were carefully dissected away, a thin musculotendinous covering on the bone being preserved. The trochanteric end of the femur was then freed and placed in the acetabulum. The detached ends of the glutaeus medius and glutaeus minimus were then gathered together in a strong suture, and fixed to the femoral shaft through drill holes as far distally as possible. The extremity was fixed in a position of abduction in a plaster-of-Paris spica for from four to six weeks, after which movement and exercises were begun.

Smith-Petersen's idea of the mold arthroplasty of the neck of the femur with a vitallium cup is too well known to require description, and it seems sufficient to reiterate that he believed that the mold served a double role,—both as an interposing substance to prevent ankylosis and also as a means of obtaining the reconstruction of new articular surfaces by stimulating the formation of fibrocartilaginous layers on either side of the smooth metallic surfaces.

Observations of the results of Whitman's and of Colonna's operations, not only in the writer's own cases but also in those of other surgeons, did not lead to the happiest conclusions with respect to the patients' comfort or function. Yet it was felt that their basic ideas were sound, and that, in the presence of an ununited fracture, with the head fragment presenting all the evidence of loss of vitality by roentgenographic examination, there was little chance of success for any surgical procedure which had as its objective the retention of the head and the securing of bony union of the fracture. It seemed possible to combine their ideas with those of Smith-Petersen, and to perform a trochanteric type of vitallium-mold arthroplasty, perhaps with improved results. The first of these operations for un-

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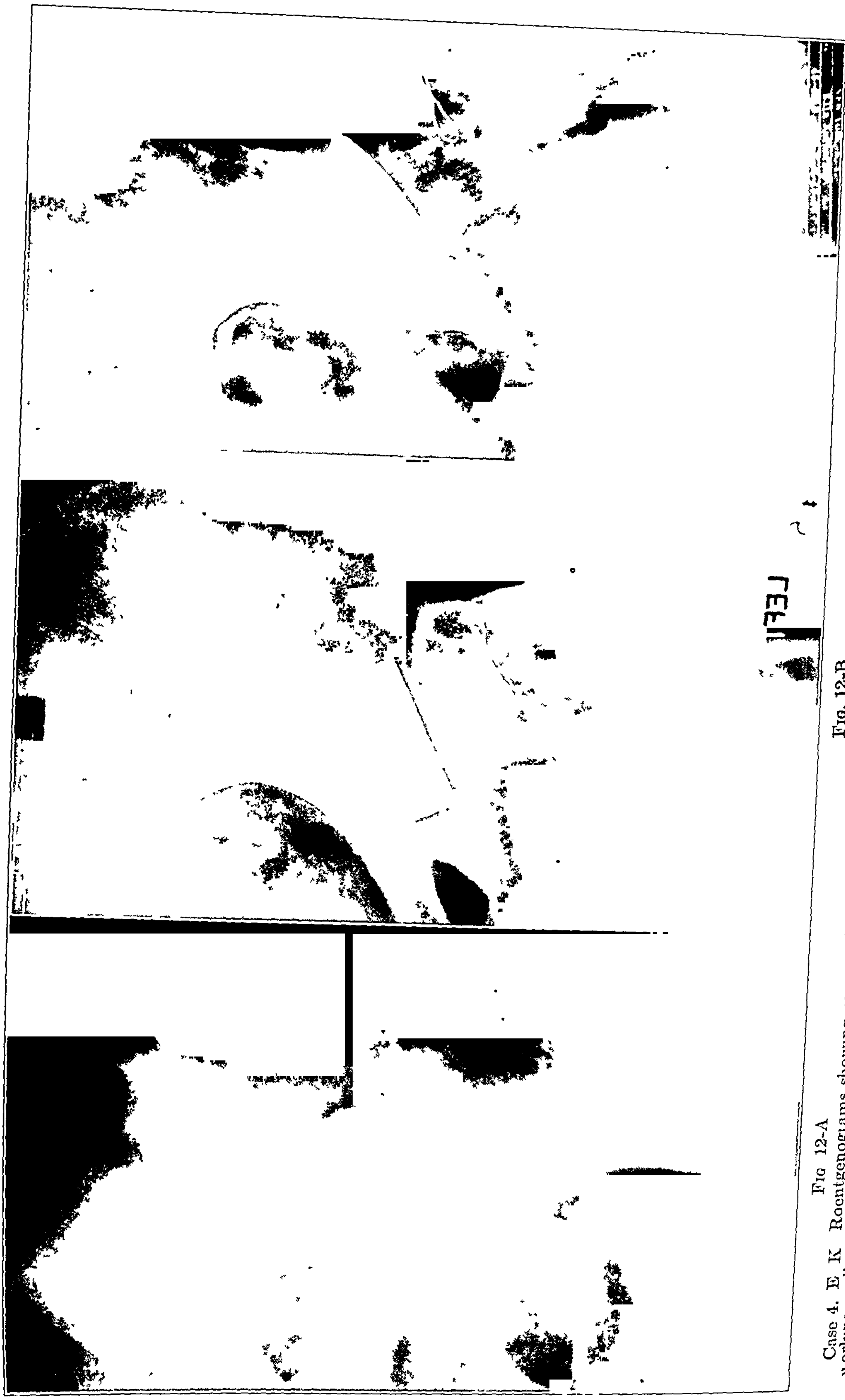

Fig 12-A

Fig. 12-B

Fig. 12-C

Case 4. E K Roentgenograms showing preoperative and postoperative condition. Fig 12-C was made one year after arthroplasty. This patient is working, walks with a cane, and has about one-half normal mobility of the hip, and no pain

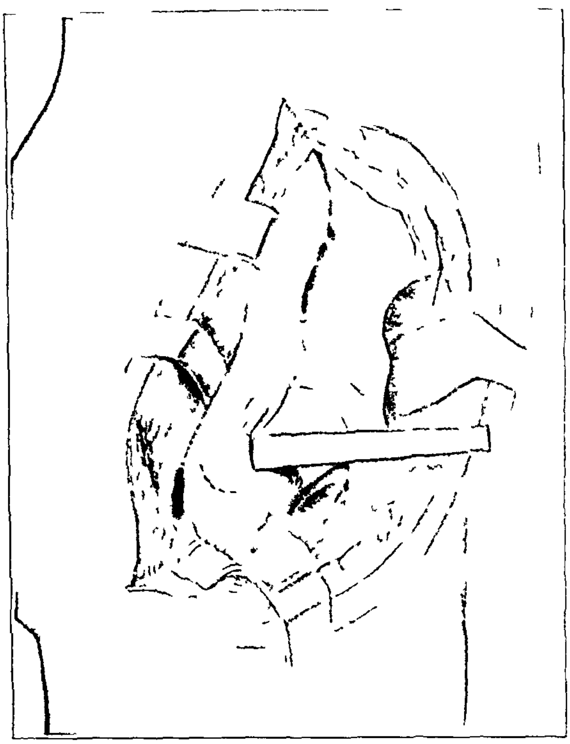

Fig 3

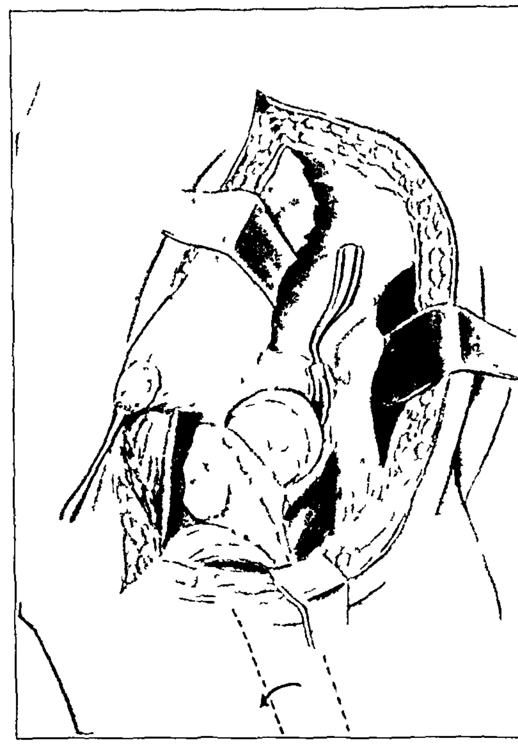

Fig 4

Fig 3 Shows the splitting off of the tip of the greater trochanter with preservation of the gluteal-muscle insertions
Fig 4 Shows the exposure and removal of the head fragment.

Fig 5

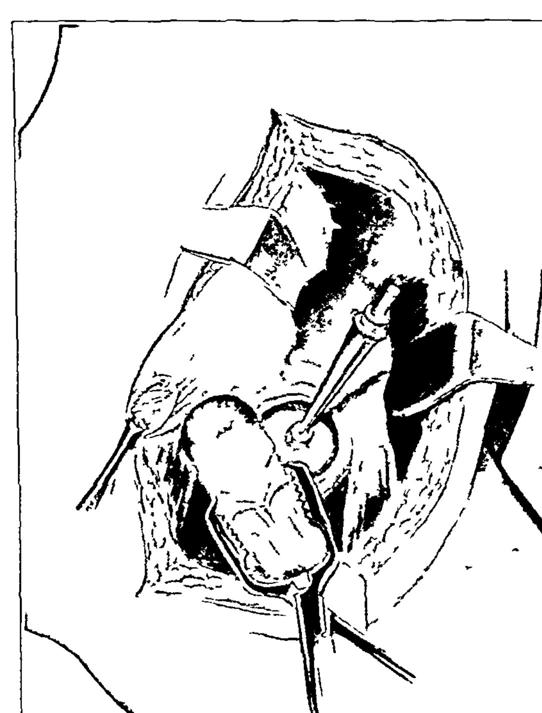

Fig 6

Fig 5 Shows the shaping of the upper end of the trochanter to fit the vitallium cup
Fig 6 Shows the reshaping of the acetabulum when necessary

the femoral shaft With an osteotome the tip of the greater trochanter is now split off, the plane of the osteotomy corresponding to the sagittal plane of the body. Before the osteotomy is performed, an effort should be made to define as well as possible the outline of the

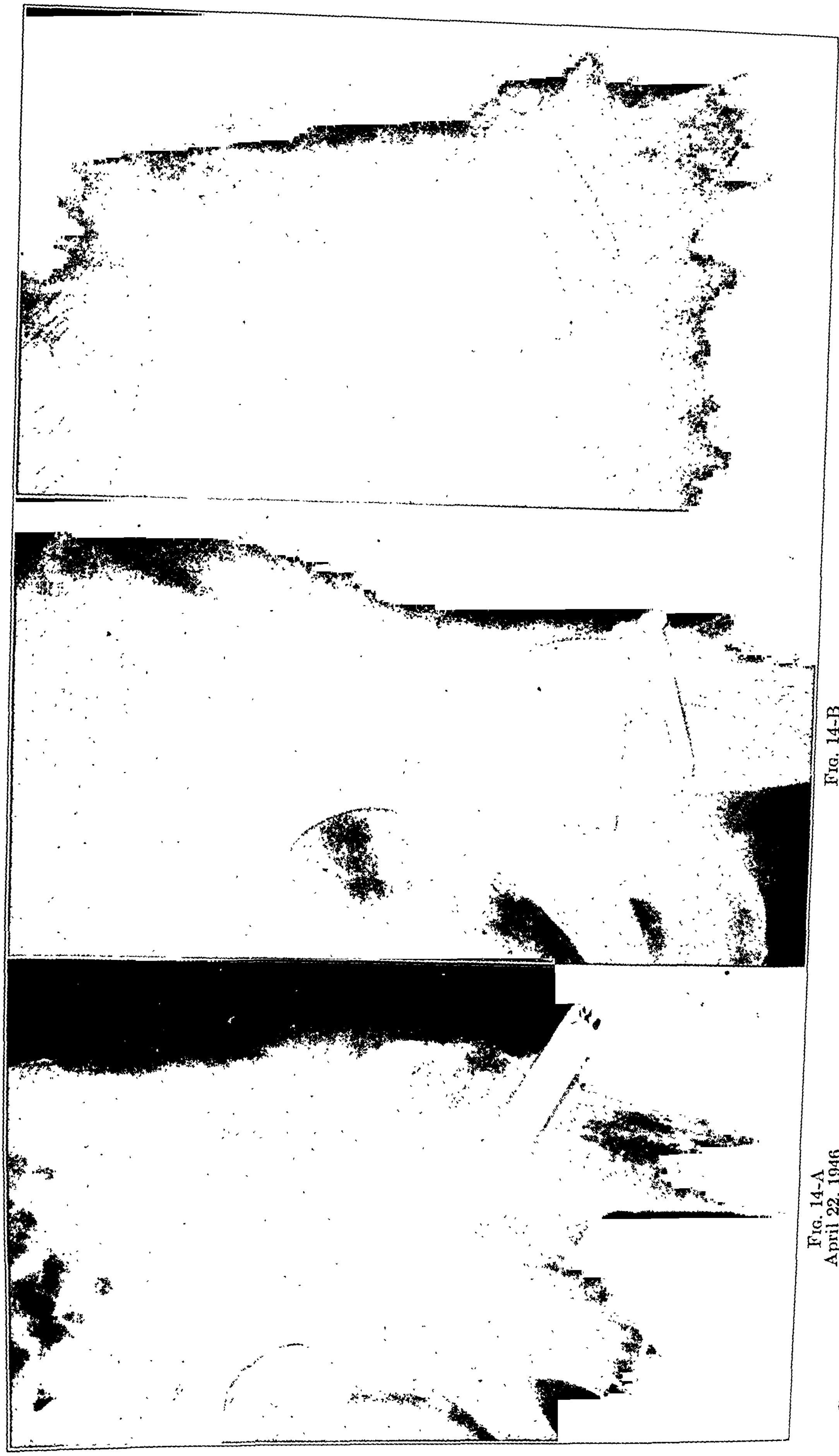

Fig. 14-A
April 22, 1946

Fig. 14-B
November 24, 1946

Fig. 14-C
November 24, 1946

Case 6. A. P. A recent case. The hip luxated following removal of the plaster, which was replaced with the hip in abduction. The result was satisfactory. The patient is now beginning to walk, and has moderate instability of the hip, but with improving function and strength.

6. With the aid of the Lane forceps and abduction of the limb by an assistant, the end of the shaft is then placed in the acetabulum. It is important, at this point, to test the stability of the new joint, both with and without the cup in place. If there is considerable tendency for the shaft to luxate from the acetabulum when the hip is adducted toward the neutral position, then the operator should seek to overcome the instability. This is generally due to one of three causes: first, impingement of the shaft against the inferior and medial border of the acetabulum, thus providing a fulcrum for dislocation; second, the use of a vitallium cup of too large size; or, third, shallowness of the acetabulum. It is necessary to trim away all ligamentous remnants which may have become interposed between the femoral shaft and the inferior border of the acetabulum and, if indicated, a part of the bony margin as well. If the acetabulum seems too small or too shallow it will be necessary to enlarge it or deepen it with the aid of doubly curved gouges, large curettes, and the convex reamers. *Care at this stage to ensure maximum stability of the joint will reap large dividends later, during the convalescent period.*

7. When the previous step has been completed, the surgeon places the end of the femur in the acetabulum with the vitallium cup in place, and maintains it there by abducting the extremity to whatever degree may be necessary for stability, generally about 45 degrees from the mid-line of the body and in complete extension. An assistant holds the limb and maintains the position until the wound has been closed and the extremity has been fixed in plaster. The surgeon then proceeds to the next step, which is the transplantation of the trochanteric fragment with its attached muscles to the shaft of the femur. The fragment is seized with a volsellum forceps or tenaculum, pulled distally as far as possible, and fixed to the femur. Various methods of fixation have been used, including stainless-steel wire, screws of different types, and nails. In the writer's opinion, screws are least satisfactory; wire gives good fixation, but the method is tedious and requires patience; while transfixion with the Stuck nail is the simplest and most practical procedure. All methods are subject to error, but even failure to secure good fixation or close approximation of the trochanteric fragment to the shaft has seemed to make little difference in the ultimate result, probably because the fragment becomes fixed by scar tissue which develops during the period of postoperative immobilization.

8. There now remains only the closure of the wound, for which there is no need of special description, and the application of the immobilizing plaster. It will be found that, with the femur abducted, there is no difficulty in suturing the divided portions of the tensor fasciae latae and, since the resulting scar is in the distal end of the muscle and there has been no interference with its nerve or blood supply, this does not affect its later function. Maintenance of the hip in a position of abduction and extension is

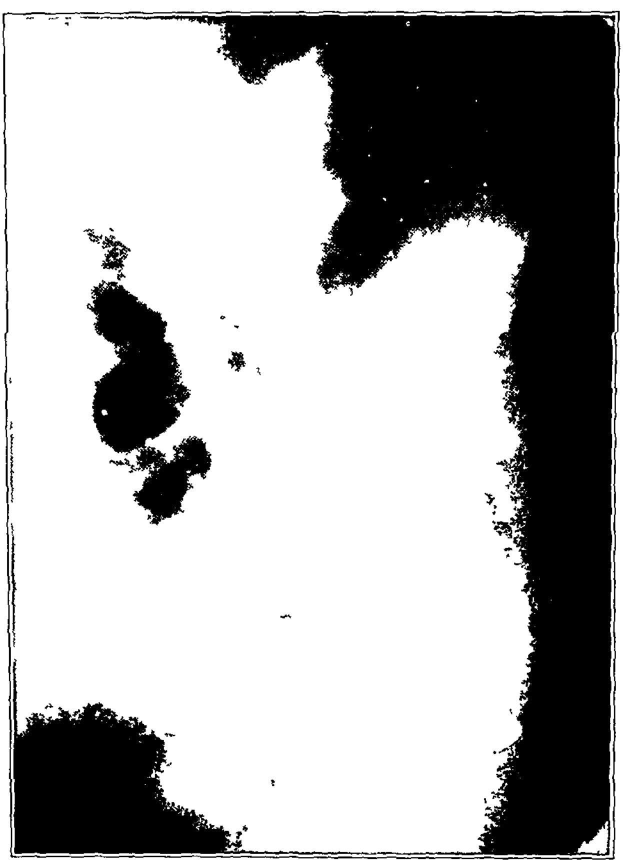

Fig. 9-A
Case 1. R. G. Condition of left hip in 1939.

a gait that approximates normal. Not all patients had such good results, but they have been free from pain, and are able to walk, and are grateful because their condition has been improved. Shortening has averaged about three-quarters of an inch.

Trochanteric arthroplasty has two advantages over the usual arthroplasty of the femoral neck. First, it eliminates the neck of the femur and, for an angular thrust, it substitutes a direct vertical thrust in the axis of the femur. This simplifies the mechanics of hip function, and reduces the likelihood of instability due to insufficiency of the iliofemoral muscles. Second, there is more abundant blood supply to the trochanter than to the femoral neck, and hence there is less chance of postoperative absorption of bone, which is frequently a troublesome feature after arthroplasty of the femoral neck.

These advantages are sufficient to more than counterbalance the single disadvantage, which is the tendency to instability of the hip in the early postoperative period, and the necessity of taking certain precautions to guard against luxation. Perhaps eventually we will find a way to make these hips more stable by the surgical implantation of a bone shelf.

While trochanteric arthroplasty is particularly indicated in the treatment of certain ununited fractures of the neck, experience shows it is of value in many other pathological conditions of the hip, especially those accompanied by destruction of the head and neck of the femur. This includes old fractures of the neck of the femur, in which union has been obtained, but where necrosis of the femoral head later developed, and old septic arthritis of the hip, in which there has occurred destruction of the head with luxation of the femur.

DISCUSSION *

Mr. Harry Platt, Manchester, England: The few brief remarks I shall make concern subtrochanteric osteotomy, which my colleague, McMurray, has practised for many years. Some time ago, when I knew I was coming to this Meeting, I asked him to give me the latest figures or late results of subtrochanteric osteotomy. There was great difficulty in tracing all of these cases, so I have taken just one or two simple facts from a letter which he sent me two days before I sailed.

He practises this operation in recent fractures of the neck of the femur, and also in cases with non-union. In twenty-three cases of subtrochanteric osteotomy performed for recent fractures, bony union followed in all. McMurray makes no mention of remote complications, such as long-delayed avascular necrosis of the head. I feel that these osteotomies probably do play an important part in preventing avascular necrosis.

McMurray wrote that, in more than sixty fractures in which subtrochanteric osteotomy had been done, he was very satisfied with the results as a whole, but that he had been unable to have two patients followed.

My own experience with the operation is much more limited, because I feel that there is no one standard operation for long-standing non-union. Subtrochanteric osteotomy has its place, and undoubtedly other osteotomies affording much more secure fixation also have an important place. As Dr. Gill has shown, there are many people suffering from non-union who are better off with an arthrodesis. I still have great affection for the Whitman reconstruction operation. Subtrochanteric osteotomy is quite popular with my colleagues in Great Britain. It is a remarkably simple operation, but it is not always successful in my hands. It is not easy to displace the shaft of the femur in the right position. If there is a failure of union between the shaft and the upper part of the femur, one is left with a femur that is very difficult to reconstruct and very difficult to arthrodese.

Dr. Carl E. Badgley, Ann Arbor, Michigan: From the standpoint of the audience, I am sure I express the general feeling when I say how well this Symposium has been presented. To know that 300 cases have been treated in Memphis with 86.5 per cent. having bony union, and aseptic necrosis developing in 33.6 per cent., and traumatic arthritis in 14.6 per cent., leads us to conclude that, in spite of the excellence of these operations for the correction of fresh fractures, there are permanent complications which we must learn to correct.

* Three papers included in this Symposium and mentioned in the Discussion were published in the January issue of *The Journal*:

Boyd, H. B., and George, I. L.: Complications of Fractures of the Neck of the Femur, pp. 13-18.

Sherman, M. S., and Phemister, D. B.: The Pathology of Ununited Fractures of the Neck of the Femur, pp. 19-40.

Smith-Petersen, M. N.; Larson, Carroll B.; Aufranc, Otto E.; and Law, W. Alexander: Complications of Old Fractures of the Neck of the Femur. Results of Treatment by Vitallium-Mold Arthroplasty, pp. 41-48.

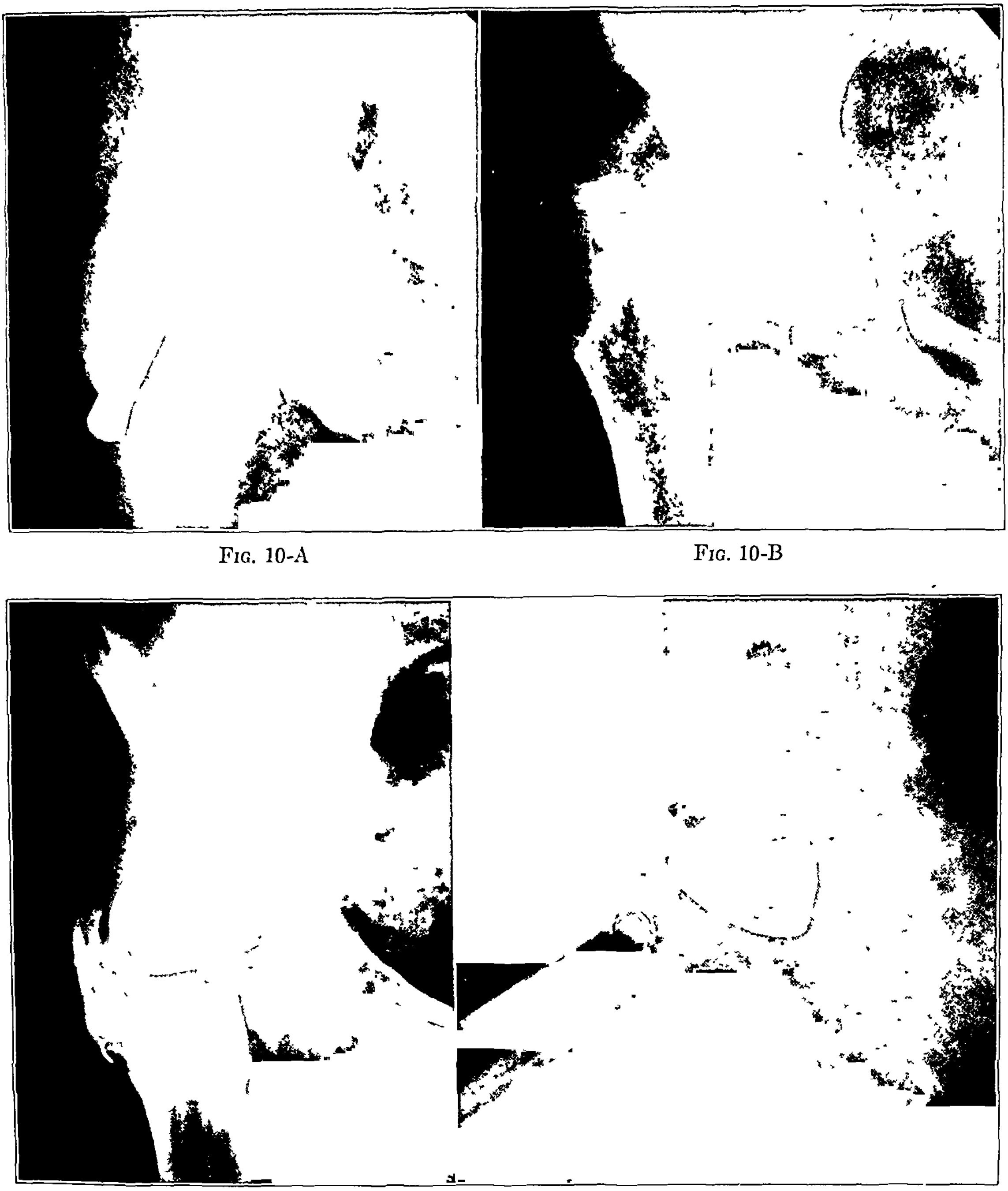

FIG. 10-A FIG. 10-B

FIG. 10-C FIG. 10-D

Case 2. R. Z. Roentgenograms made at different periods during treatment. Fig. 10-A: Condition in November 1940. Figs. 10-C and 10-D were made two years after arthroplasty. This patient is working in domestic service. She carries a cane on the street, but walks without a cane in the house. She has about two thirds of normal mobility of the hip.

Postoperative Treatment

Depending upon the stability and security of the hip which are determined at the time of operation and by postoperative roentgenographic examination, the immobilizing apparatus is removed at the end of from four to six weeks. Since the purpose of this retentive apparatus is to maintain abduction and to prevent luxation, there is no objection to freeing the knee joint at a considerably earlier period in order to permit mobilization and exercises.

Following the removal of the plaster casing, mobilizing exercises of the hip are started. A sling is placed under the knee and connected to a hand pull by means of pulleys

LAMINECTOMY AND FORAMINOTOMY WITH CHIP FUSION

Operative Treatment for the Relief of Low-Back Pain and Sciatic Pain Associated with Spondylolisthesis

BY HENRY BRIGGS, M.D., AND SIDNEY KEATS, M.D., EAST ORANGE, NEW JERSEY

From the New Jersey Orthopaedic Hospital and Dispensary, Orange

Forward gliding of the lumbar vertebrae, or "spondylolisthesis", has long been of special interest to the orthopaedic surgeon, but only as a congenital anomaly of the spine. Since the deformity was first recognized in four anatomical specimens and described by Killian in 1854, the literature has been replete with accurate descriptions of this condition. Etiological considerations still differ, however. Although most authors are agreed that the defect is congenital in origin, the pathogenesis of this condition continues to be a subject of controversy. In recent years, however, greater emphasis has been placed upon calling attention to the clinical manifestations of this deformity and to measures for the treatment thereof than upon theories of genesis.

Spondylolisthesis is more than an anatomical curiosity; it is a fairly common cause of low-back pain, often with sciatic radiation. Caldwell has noted recently that, among those patients at his clinic with low-back symptoms severe enough to require medical attention, one out of every ten presented the deformity characteristic of spondylolisthesis. Meyerding[5], too, has called attention to the rather frequent association of protruded intervertebral discs with spondylolisthesis. In our own study of patients with low-back pain and sciatic pain, we have often seen patients exhibiting this deformity, who, because of trauma, obesity, or occupational strain, presented disabling backache and pain in the legs.

By the very nature of the deformity, chronicity of symptoms is the rule. The permanency of the results following conservative treatment—such as immobilization or recumbency—has been notoriously poor; and patients with such backs continue to be susceptible to trauma and not able to carry on routine physical activity. Recently, more thought has been given to operative measures for the treatment of spondylolisthesis. Since reduction is not possible, efforts have been directed chiefly at improving the support of the lumbosacral vertebrae, taking the stretch and strain off muscles and ligaments, and reducing the possibility of further progressive subluxation. Caldwell and others have noted that many of these patients fail to obtain complete relief of the backache and leg pain, despite roentgenographic evidence of solid bony fusion after operation. We have been concerned for some time with the development of an operative technique which will not only stabilize the lumbosacral junction, but will afford lasting relief from the disabling symptoms of backache and leg pain.

To date, the authors have operated upon eighteen patients for the relief of backache and leg pain associated with spondylolisthesis, utilizing the technique described here. In determining the criteria for operation, we have paid more heed to the severity of the symptoms than to the grades of displacement, as described by Meyerding[4]. It is the authors' conviction that, for those patients who must work and whose condition permits, surgical intervention will afford the most lasting degree of relief from pain and will strengthen considerably a congenitally weak link in the vertebral column. Nine patients were subjected to a procedure which was essentially that of laminectomy, followed by a chip fusion of the involved segments; an additional nine patients, who had pain of sciatic radiation in addition to the low-back pain, were relieved by foraminotomy in combination with laminectomy and chip fusion.

performed. Many had undergone previous operations elsewhere, and to narrate the entire history would unduly extend this article and exhaust the patience of the reader It is hoped, therefore, that a summary of the results will suffice.

Of the nine patients, excellent results were obtained in four and they are able to lead

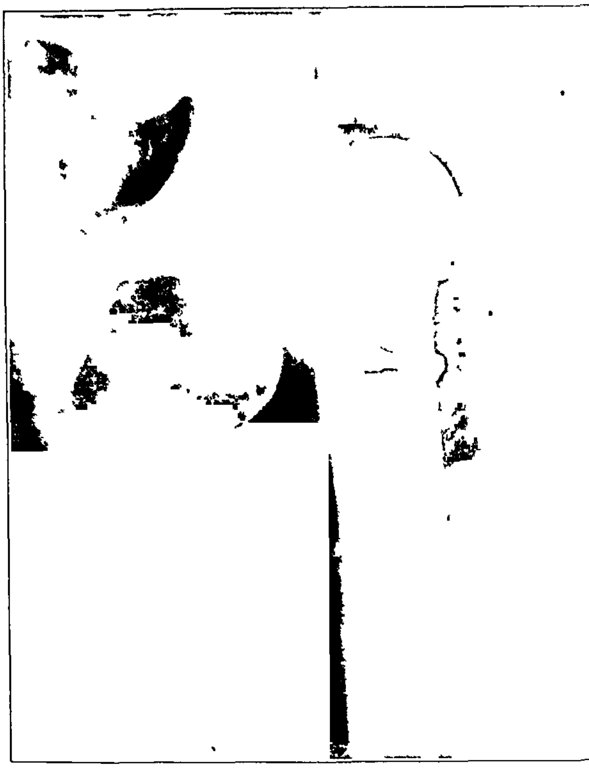

Fig 11-B

Fig 11-C

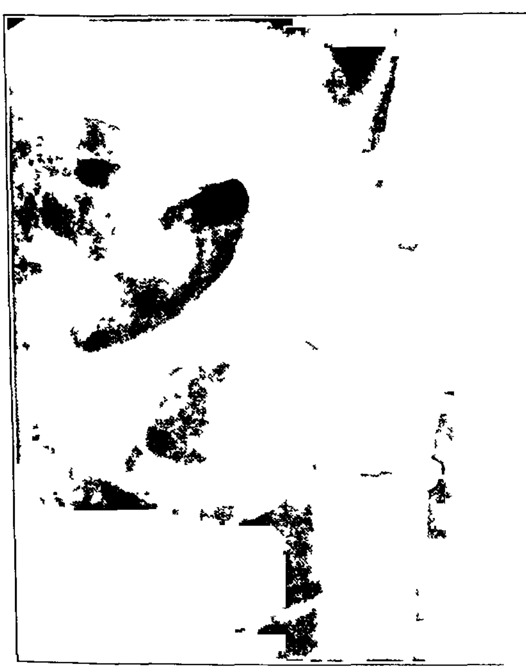

Fig 11-D

Fig 11-E

Roentgenograms taken during course of treatment
Fig 11-B First postoperative roentgenogram shows subluxation of cup from acetabulum
Fig 11-C Shows replacement by abduction of the hip
Figs 11-D and 11-E were made one year after arthroplasty Patient walks with slight instability, and has free range of motion and moderate power of control She uses a cane on the street The double cortical line of the femur is due to extensive xanthomatosis of the femur

bone first, rather than leave it until the end of the operation. Returning to the mid-line, the operator divides the supraspinous ligaments down to the spinous processes; and a subperiosteal stripping of the spinous processes and laminae is carried out, starting over the lower sacral segments. Extreme caution must be observed if there is a spina bifida defect of the sacral segments,—a fairly common anomaly associated with spondylolisthesis. With bone-cutting forceps, the spinous processes of the exposed sacrum and the fifth lumbar vertebra, and part of the spinous processes of the fourth and third lumbar vertebrae, are removed and broken up into small chips. With a rongeur, the movable portions of the laminae of the fifth lumbar vertebra are carefully removed from the underlying epidura tissue. The ligamenta flava between the fourth and fifth lumbar vertebrae and the lumbosacral interval are completely removed. A search for nerve-root impingement is now carried out by exploring the disc, and by probing the course of the nerve roots with catheters

If there is no evidence of root compression, preparations for the fusion are made. The cartilaginous defect of the pars interarticularis or "isthmus" is thoroughly curetted until the raw surface of the pedicle stump is encountered. The cartilage of the articular facets between the fourth and fifth lumbar segments is then thoroughly curetted or denuded with a Hibbs rasp. These facets lie just superior to the pedicle stump. The exposed cortices of the laminae of the fourth lumbar vertebra are turned back to form buttresses for bone chips. The facets of the sacrum are then curetted and gouged out. The exposed laminae of the sacrum are denuded of cortical bone. All the chips thus removed are saved for the fusion. Epidural bleeding is controlled by small packs saturated with soluble thrombin. Fat or muscle tissue is used to cover the nerve roots that are exposed on both sides. The mass of chips accumulated from the stripping of the laminae and the fragmentation of the spinous processes and those removed from the ilium are now placed laterally on the bony bed, which extends from the buttresses of the fourth lamina to the sacrum, and over the dura in the mid-line. The smaller chips are placed on the dura, the larger chips superficially, and occasionally strips of the ilium are used laterally. Muscle and fascia are sutured with No. 00 chromic catgut; subcutaneous tissue is approximated with the same material, and the skin is closed with interrupted cotton sutures. A flat bandage of gauze is placed over the incision and covered with strips of adhesive. During the operation, the patient is given a continuous intravenous infusion of glucose in saline, and from 500 to 1,000 cubic centimeters of whole blood. After the operation, the patient is placed on a rather firm bed in the recumbent position; prostigmine methylsulfate, in a strength of 1 to 2,000, is administered intramuscularly every six hours for forty-eight hours to avoid distressing abdominal distension. The patient is turned onto his abdomen or side several times a day. This tends to avoid the formation of pressure sores or necrosis of the wound edges. The wound is usually inspected at the end of four days, at which time a fresh dressing replaces the original stiff, blood-soaked dressing. At the end of from ten to fourteen days the sutures are removed; fresh dressings are applied; and a leather-covered steel support is fitted to the lower part of the back, which the patient wears while recumbent in bed. At the end of five or six weeks, the patient is permitted to get up, wearing the support. He is advised to continue to wear it for at least six months after the operation, and is cautioned to avoid stooping, heavy lifting, and vigorous physical activity during this period. Most patients are able to resume their usual occupations in from six months to a year after operation.

The second arbitrary group of patients includes those who had a history of leg pain associated with the backache. Severe pain in the legs in this group of patients, who have the recognized deformity of spondylolisthesis, is indicative of nerve-root involvement, whether it be attributable to a pathological intervertebral disc or to soft-tissue and laminal pressure on stretched nerve roots. In the absence of direct pressure on the roots by a herniated disc, a thorough exploration of the intervertebral foramina is necessary. Simple laminectomy alone, our experience has proved, is not adequate to relieve the oppression

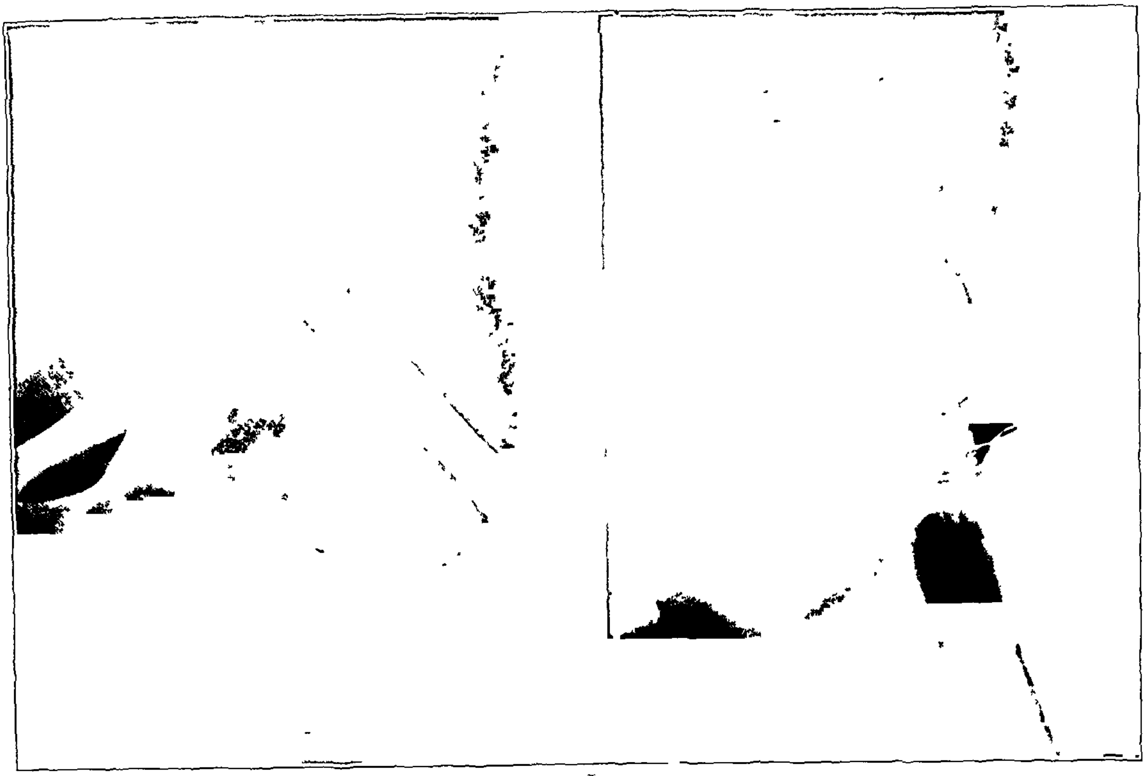

FIG. 13-A FIG. 13-B

Case 5. L. S. Patient, aged twenty-two, with old ununited fracture of the neck of the femur. It is now seven months since the operation. The patient has been married, and is carrying on full domestic duties.

normal lives. Of these, one has practically normal hip function and walks without a cane, while the others have only slightly less satisfactory results. Two are married and perform all their domestic duties, while the other two are working at jobs which require them not only to get to and from work by means of public transportation, but to be on their feet a large part of the day.

The results in two of the patients are graded as good. One of these is a woman of sixty-five with a long history of vague articular disability preceding the fracture of her hip. She also had extensive xanthomatous changes in the bones of her lower extremities, verified by the pathologist of the hospital after examination of the bone tissue removed at operation. She has excellent function of the hip without pain, but walks with crutches when outside her apartment.

The other patient, also a woman, aged sixty-two, before seeking relief, had endured the crippling effects of an ununited fracture of the neck of the femur for twenty-five years, but with increasing pain and disability. As a result of operation, she has obtained relief from pain and improved stability. She has limited mobility of her hip, but has been able to return to work in domestic service.

One patient, a man, aged fifty-one, sustained a fracture of the neck of the femur during military duty in August 1944. The fracture was reduced and nailed elsewhere with a resulting postoperative infection. The nail was later removed, but a draining sinus persisted for about one year. He presented himself in November 1945, walking with crutches, with a displaced ununited fracture and the head ankylosed in the acetabulum. Trochanteric arthroplasty was performed on November 8, 1945, and, in spite of penicillin therapy, a low-grade postoperative infection developed. The metallic foreign material was removed February 21, 1946, following which his wound slowly healed. When last seen, on September 8, 1946, his wound had healed, and he was walking with a cane, without pain. There was limited mobility of his hip with about 30 degrees of flexion, 15 degrees of abduc-

CASE 5. J. S., a glass grinder, had an uneventful postoperative course and was discharged from the Hospital on an ambulatory basis, wearing a low-back brace. The patient was not conscientious in his follow-up visits, but when last heard from he had no discomfort in the lower part of his back.

CASE 6. A. G. was seen forty-four months after operation. At that time she was doing her housework without pain and had long since discarded her back support.

CASE 7. J. S., a mason, was examined forty-six months after operation. He stated that he had been working ten or twelve hours daily as a bartender, and in his spare time worked as a mason. He had no pain in the lower part of his back, but did notice an occasional cramp in the back of the legs. He no longer wore his brace.

CASE 8. G. G., a thirteen-year-old schoolgirl, was relieved of her backache for six months after a laminectomy and chip fusion. At the end of that time, she began to suffer pain of left sciatic radiation. A foraminotomy of the fifth lumbar intervertebral foramen was subsequently performed, with a revision of the fusion on the left side. The patient was able to leave the Hospital without symptoms, on the fourteenth day after operation, without low-back support. When examined, six weeks later, she was back in school and had no discomfort in the back or legs.

CASE 9. J. P., when seen six months after the operation, was feeling well. He had no pain and was ready to discard his brace and return to work.

The second group of patients—those with excruciating leg pain as well as backache—were relieved by a technique consisting of foraminotomy for the relief of nerve-root oppression, as well as laminectomy and chip fusion. The results in these cases were as follows:

CASE 10. C. A., a young housewife, who had had "double subluxation" and severe right sciatic pain before operation, was examined twenty-one months after the operation. She stated that she had been

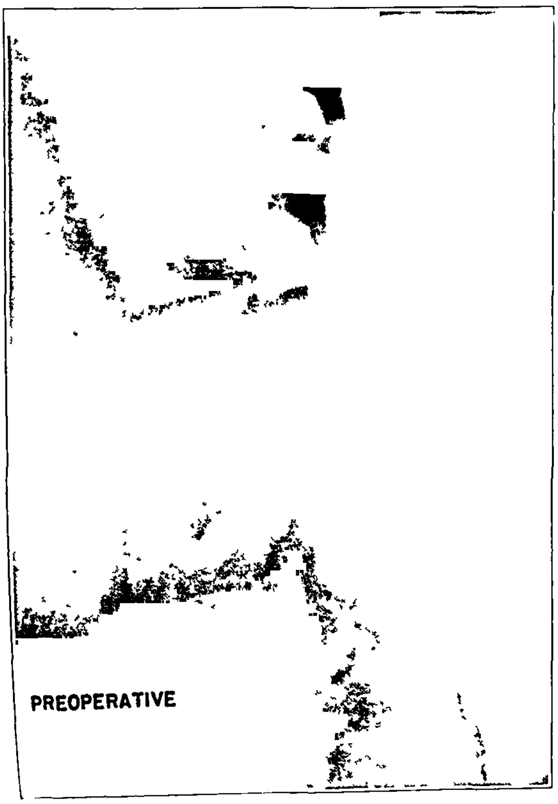

FIG. 1

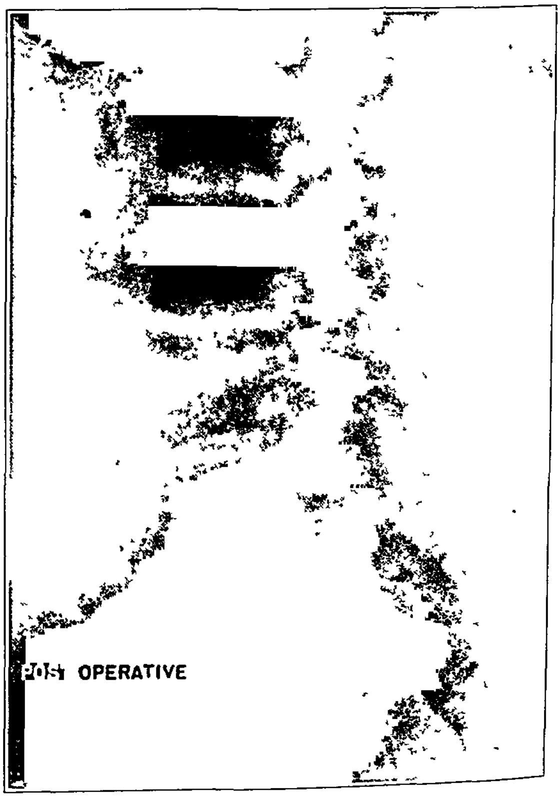

FIG. 2

Fig. 1: Case 11. S. A., aged thirty-four, presented a two-year history of backache and bilateral leg pain of sciatic distribution, after he experienced a severe wrench of his back while pulling a crane. Roentgenograms showed the typical pedicle defect of the fifth lumbar vertebra, with slight forward displacement of the body of that vertebra on the sacrum. The degree of displacement was more pronounced in roentgenograms taken with the patient standing. There is an associated spina bifida defect. The patient was completely relieved of pain after foraminotomy and laminectomy of the fifth lumbar vertebra, and a chip fusion augmented by cancellous bone from the iliac crests. These procedures were carried out on November 28, 1945.

Fig. 2: Roentgenograms, four weeks after operation, illustrated the extent of the foraminotomy and the application of the mass of bone chips, with obliteration of the pedicle defect. When last examined, on September 18, 1946, the patient had returned to work and was completely free of pain.

tion, and an equal amount of adduction. The roentgenographic examination showed good stability with a good joint space, and there seemed to be an excellent prospect that the motion would increase. The patient was pleased with the improvement over his preoperative condition, but the result is graded as fair.

There were two bad results. The first was in a man of elderly appearance, fifty-one years old, who consulted the writer in February 1943, two months after sustaining a fracture of the neck of the femur and a compression fracture of the second lumbar vertebra, when he was shocked and thrown to the ground while working on a high-voltage electric line in Trinidad. The fracture of his hip was reduced elsewhere and fixed by the insertion of four Kirschner wires. Upon arrival at the Hospital for Special Surgery, the roentgenographic examination showed malposition of the fracture, with one wire penetrating the acetabulum and passing far into the pelvis. On February 27, 1943, operation was performed, with removal of the wires, realignment of the fracture, and fixation with a Smith-Petersen nail and a bone graft. The vertebral fracture was immobilized in a plaster jacket applied in hyperextension. The roentgenographic examination on March 11, 1944, showed non-union of the fractured hip with necrosis of the head fragment. Trochanteric arthroplasty was performed on May 6, 1944. No complication occurred, but satisfactory mobility of the hip never developed, in spite of excellent appearance in the roentgenogram. Subsequently, on January 28, 1946, because of limited mobility and persistent abduction deformity with pain, another operation was done, with removal of the cup and a fusion with nail fixation. From this procedure he obtained a good result.

The second poor result was in a woman of over seventy, who, for nineteen years prior to injury of her hip, had suffered from rheumatoid arthritis with chief involvement of her hands, feet, and knees. Nevertheless, she had been able to get about and be independent. In January 1943, she fell out of bed during an attack of pneumonia, and fractured the left hip. She was operated upon elsewhere, and the fracture was reduced and fixed with a nail. Non-union developed, with marked absorption of the fragments of the neck. In spite of her various disabilities, which included hypertension and an enlarged heart, she demanded to be operated upon in order to get back on her feet. She was considered a poor operative risk, but, in response to her pleas and those of her physician, the operation of trochanteric arthroplasty was reluctantly undertaken on February 11, 1944. She survived the operation, but the postoperative course was stormy, with coronary thrombosis and extensive cardiac infarction and collapse. It was necessary to remove the plaster-of-Paris spica, with resulting luxation of the hip for which nothing could be done. She was discharged from the hospital in a wheel chair some four months later, and she died shortly afterward.

A summary of these nine cases, therefore, shows the results excellent in four, good in two, fair in one, and poor in two. Of the two poor results, one patient obtained a good result by hip fusion and the other died from five to six months after operation. Seven of the patients were women and two were men. The ages of the patients ranged from twenty-two to over seventy years, but most were between fifty and sixty years.

DISCUSSION

It should be made clear that the writer is not proposing trochanteric arthroplasty as the proper method of treating all ununited fractures of the neck of the femur. Excellent results have been obtained by bone-grafting procedures in some cases, and in others by the various methods of upper femoral osteotomy; but these methods are doomed to failure in cases where there is clear evidence of necrosis of the femoral head, or when there has been extensive absorption of the neck. In such cases, improvement can be obtained only by removing the head fragment, and then performing either a fusion or an arthroplasty of the Whitman or trochanteric types.

Of the joint reconstruction operations, the writer has found that trochanteric arthroplasty has given the best results. The patients with the best results are able to walk with

stretching of the nerve roots, on pressure of the roots by unattached posterior elements of the defect and soft tissue, or on a combination of both. We have noted on three occasions, however, in explorations of the foramina, that, upon unroofing the intervertebral foramina, the liberated roots seemed to bulge out and expand, and appeared to take a more direct route peripherally. It may well be that the roots are angulated and compressed over the posterior rim of the body of the first sacral segment. At any rate, complete relief of pain was accomplished by foraminotomy. Surgical fusion alone will not relieve sciatic pain. We are of the opinion, then, that relief of sciatic pain in spondylolisthesis can be satisfactorily obtained by laminectomy and intervertebral foraminotomy in conjunction with a modified chip fusion. A broad analysis of the cases presented leads us to believe that, by the operative technique in the treatment of spondylolisthesis described here, the following results can be obtained:

1. Relief of backache and pain of sciatic radiation.
2. Stabilization of a congenitally weak and troublesome link in the vertebral column.
3. Rehabilitation of these patients to the point where they can follow their occupational endeavors,—manual or sedentary.
4. Elimination of permanent cumbersome braces.

There is, too, every indication to believe, after months of follow-up study, that permanent good results can be achieved.

CONCLUSIONS

Backache and severe leg pain, associated with spondylolisthesis, can be relieved by surgical methods, as shown by the eighteen cases presented. The technique of operation is concerned with two principal problems: first, stabilization of the weak link in the spinal column to relieve tension and strain on the associated muscles and ligaments and to prevent further progression of the subluxation; and, second, relief of the nerve-root oppression responsible for the sciatic pain. Nerve-root pressure was accounted for by a protruded intervertebral disc in only one of the nine cases of sciatica; the remaining eight patients were relieved of pain when the involved intervertebral foramina were unroofed. The operative technique which appears to offer the greatest permanent benefit and the most dramatic relief of pain is a combination of laminectomy, intervertebral foraminotomy, and chip fusion.

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When I heard Dr. Sherman give her report on the pathological changes, I could not help but feel how important it is to understand the clinical pathology demonstrating the lesion.

I think the problem consists of two factors: one of non-union, and one of degenerative changes. We have two approaches; we have correction where the fault lies, and we have the possibility of producing another strain to correct that fault. My philosophy of the treatment in the past has been that I do not wish to produce another strain. My plan has been to correct the lesion at its point of occurrence. We have attempted to obtain union in ununited fractures with a bone graft. I know little about osteotomy, but I am amazed at the excellent results. I can recall Naughton Dunn saying in Chicago: "Why worry if I break a hip in America?" He went on to say that if he had a fresh fracture, he would let Smith-Petersen nail it, or he could have Goldthwait treat it.

Dr. Paul C. Colonna, Philadelphia, Pennsylvania: I assume I was asked by your Chairman to take part in this discussion because of a trochanteric reconstruction operation that I originally presented as my thesis to this Association in 1935.

As we have heard today, there are a number of surgical procedures that have been devised and which are available for dealing with the problem of ununited fracture of the neck of the femur. It would be wise to be familiar with the indications and contra-indications for each. To approach a decision regarding the type of operation to be selected for the individual case, one must first decide whether the head fragment can be saved, or whether the degree of aseptic necrosis requires its removal. My remarks will be restricted to the type of case in which removal of the head fragment is regarded as necessary.

In March 1931, I did my first trochanteric reconstruction operation at Bellevue Hospital, and the results in this first patient were carefully examined for over a year before it was repeated on another patient in August 1932. To date, I have repeated the operation on over thirty patients, and a report on 121 of these operations performed by different surgeons throughout the country was published in *The Journal of Bone and Joint Surgery*, July 1939. It was and still is recommended for those cases with frank non-union, marked aseptic necrosis of the head, and shortening of the extremity. The operation removes the necrotic head fragment, and places the greater trochanter of the femur deep into the acetabulum, after all of the neck fragment has been chiseled off. Stability is further assured by transplanting the abductors downward into a prepared trough on the lateral surface of the shaft. The operation intentionally avoids chiseling off the greater trochanter. It thereby produces a lengthening of an already shortened extremity. If the transplanted abductors are firmly anchored into the shaft of the femur, and adduction is guarded against by the simple expedient of keeping a hard pillow between the legs for the first few weeks after the plaster has been removed, any tendency to dislocation of the greater trochanter will be avoided.

Therefore, the aim of this reconstruction operation has been: first, to convert an unstable hip into a stable one, and to produce a direct weight thrust when the patient is bearing weight; second, to obtain free mobility. This is obtained by preventing a fresh bony surface from being exposed to the cartilage of the acetabulum, as in the Whitman operation. The third object is to add length to an already shortened extremity.

Dr. Smith-Petersen has kindly called his operation a "modification of the trochanteric reconstruction" operation, and it seems to me that any procedure which ensures added length possesses a very desirable feature. I hope he will pardon my failure to see the necessity for introducing a cup, if there is absorption of the neck and necrosis of the head. It seems to me unnecessary, when one has a fibromuscular covering of tissue over the area of the greater trochanter which fits against good articular cartilage of the acetabulum. In the procedure which I have been following, the approximation of these two structures of nature has certainly produced an excellent range of motion with stability. However, if there is a marked arthritis involving the joint space, I would prefer either the procedure described by Dr. Smith-Petersen this morning or an arthrodesis.

Dr. Wilson has written me that his operation is similar to mine "but different". I would agree to this distinction. After hearing his paper and seeing the slides, I would feel that his is rather a Whitman operation, with the introduction of a cup over the cut surface of the femur. I consider stability to be essential in any weight-bearing joint; but, in addition, I believe a wide range of controlled movement and lengthening of an already shortened extremity are also very desirable and much-to-be-sought-after features.

Dr. Harold B. Boyd, Memphis, Tennessee: Dr. Harris has suggested that the presence of the Smith-Petersen nail may cause the triangular area of aseptic necrosis. The nail may be a contributing cause, but, in our opinion, it cannot be the sole cause. We have seen similar triangular areas of aseptic necrosis in the head of the femur following impacted fractures, in which union has been obtained without internal fixation, and following dislocations of the hip in which no fracture occurred.

In our experience, bone-grafting of the neck of the femur has not shown any definite proof that the graft stimulated revascularization of the head of the femur. Sometimes, in the patient who appeared to have a living femoral head at the time of the bone graft, aseptic necrosis in the head later developed.

(*Continued on page 358*)

TABLE I

SPECIFICATIONS FOR 18–8 SMo* FOR PLATES AND SCREWS

Metal	Per Cent.
Chromium	17 to 20
Nickel	10 to 14
Molybdenum	2 to 4
Manganese	Not more than 2
Silicon	Not more than 0.75
Carbon	Not more than 0.08
Phosphorus	Not more than 0.03
Sulphur	Not more than 0.03
Iron	Remainder

* For use in plates and screws, it must be cold-worked to a Rockwell hardness between C-30 and C-35.

defective items have been produced, and the following deficiencies in physical characteristics and design have been observed:

DEFICIENCIES NOTED IN PLATES

1. *Improper Design of Plate*: The mid-section of the commercial Sherman plate is one of the narrowest parts and the weakest part of the plate, whereas it should be the strongest. Furthermore, this mid-section is so long in proportion to its cross-section area that it renders the plate too flexible for rigid fixation of the bone, in spite of proper operative technique and firm fixation of the screws. Many plates, bent or broken in the mid-section, have had to be removed from patients in both military and civilian practice. In this respect, it should be noted that the original patent (1914) of the Sherman plate provided for a thicker as well as a wider mid-section than was subsequently adopted, although there is no apparent reason for the change to the weaker design. The catenoid design, found in the Sherman plate, provides for more uniform bending than in the case of a plate which is straight throughout, since the straight plate tends to bend more sharply at the screw holes.

2. *Variable Hardness in the Metal*: The hardness has varied, especially among manufacturers, from Rockwell B-80 to C-35†. The former, softer metal is not rigid enough to meet requirements. In so far as possible, the hardness should be uniform, since a variation in hardness has had the same effect as variable composition in producing electrochemical reactions. In some corroded plates and screws examined at the National Bureau of Standards, the corrosion occurred between soft screws and hard plates, both of satisfactory chemical composition. Therefore, a uniform hardness of Rockwell C-30 to C-35 has been adopted for the finished plates and screws.

3. *Improper Manufacturing and Inspection*: This includes improper curvature of the plate, wrong shape of countersink so that the screw head does not fit the hole in the plate, and variable-sized holes.

DEFICIENCIES NOTED IN SCREWS

1. Examination by the National Bureau of Standards of more than 600 screws, obtained from several manufacturers, revealed marked variations, as follows:

(a) Major diameter of screw	0.132 to 0.148 inch
(b) Depth of thread	0.015 to 0.028 inch
(c) Width of thread crest	0.003 to 0.009 inch
(d) Width of space root of thread	0.002 to 0.029 inch
(e) Root diameter	0.086 to 0.108 inch

The combination of variable-sized screws and variable-sized holes in the plate sometimes resulted in screws which would pass through some, but not all, holes in the same plate.

† The designation Rockwell hardness refers to the hardness of a metal, as measured on an arbitrary scale, by its resistance to indentation by a sphero-conical point. The degree of hardness is correlated with the strength of the material.

ANALYSIS OF CLINICAL DATA

Eight patients were women and ten were men. Their ages varied from thirteen to fifty-three years. In the youngest patient, the symptoms developed at the age of eleven. Three patients were under twenty, five were in their twenties, four in their thirties, five in their forties, and one was over fifty. Nine patients were employed in occupations entailing vigorous physical activity; one patient was a housewife and another an office worker.

Pain in the lower back was the outstanding complaint in all cases. Pain in the legs was described as severe in nine patients. Of those nine, pain in both legs was noted in only two cases, down the right leg in four, and in the left leg in three. Pain in the coccygeal area was present in three patients. The duration of pain before operation was less than one year in five cases, from one to four years in nine patients, and from five to ten years in two patients; two patients had had pain for as long as fifteen years. A definite, sudden onset of pain—usually due to a fall or to heavy lifting—was noted in eight patients; no direct attributable cause was known in ten. The pain was almost always described as periodic, rather than constant. Accentuation or precipitation of the pain by coughing, sneezing, or straining was noted only in two patients. Four patients had worn braces with relief of the low-back pain but not of the leg pain; this relief was only temporary.

The knee-jerk or ankle-jerk response was diminished or absent in four cases. Numbness in the extremities was noted in five patients.

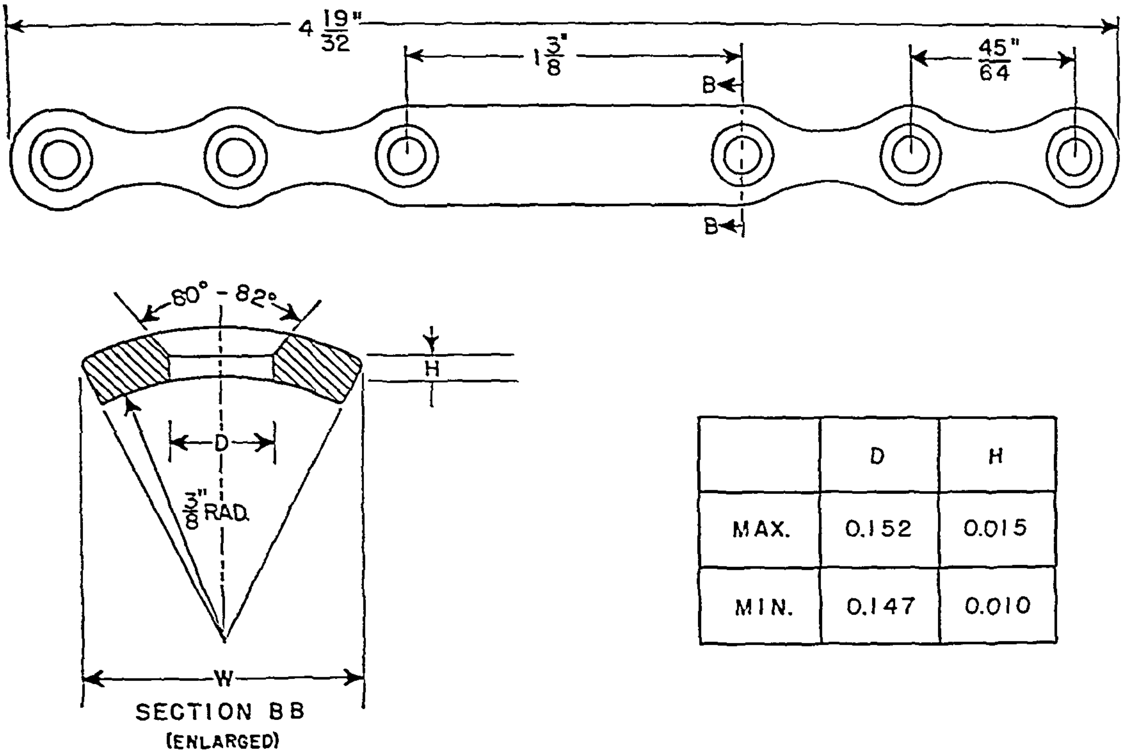
The location of the spondylolisthesis was between the fifth lumbar vertebra and the sacrum in fourteen cases, and between the fourth and fifth lumbar vertebrae in one case; a "double" subluxation—fourth lumbar on fifth lumbar vertebra and fifth lumbar vertebra on the sacrum—was noted in two cases; and a forward gliding of a lumbarized first sacral segment on the second sacral vertebra was present in one case. An associated spina bifida defect in the sacrum was present in four of the patients.

OPERATIVE TECHNIQUE

The authors have approached the operative relief of low-back pain and sciatic pain, associated with spondylolisthesis, with the object of determining the cause of both the backache and the radiating pain. They have come to believe that it is necessary to examine the intervertebral disc and the nerve roots in this exploration. To explore the disc adequately a hemilaminectomy, or preferably a complete laminectomy of the loose laminae, is indicated. To explore the nerve roots, not only must the loose laminae be excised, but the inferior facet, usually the first sacral facet, and some of the contiguous pedicle must be removed. In other words, the intervertebral foramen must be completely unroofed by a foraminotomy, as described by Briggs and Krause. Following such an exploration, a fusion is necessary. A chip fusion, as described by Briggs and Milligan, has proved completely satisfactory.

The cases have been arbitrarily divided into two groups for purposes of presentation. The first group comprises those patients who presented no history of leg pain, and at operation showed no evidence of root pressure. The operation thus consisted of a laminectomy of the unfused laminae, followed by a modified chip fusion. The technique of this operation is as follows:

With the patient in a prone position, supported by sandbags under both ilia so that the abdomen is not compressed, pentothal sodium and nitrous oxide with oxygen are administered as an anaesthetic. The use of the sandbags prevents increased intra-abdominal pressure and markedly reduces the epidural bleeding. A longitudinal incision is made over the spinous processes, from the third lumbar vertebra to the mid-sacrum. A right-angle incision also is made, to expose the crest of the ilium. The iliac crest is denuded subperiosteally, a section of the crest is removed, and a quantity of chips gouged out. These are saved for later use in the fusion. Experience indicates that it is wiser to prepare this



	D	H
MAX.	0.152	0.015
MIN.	0.147	0.010

Fig. 1

Details of modified Sherman plate with wide mid-section. The dimensions apply to Plate B, Table II. Note that the countersink has the same angle (80 to 82 degrees) as the screw head in Fig. 2.

is seldom done in bone surgery, because pretapping adds one additional step to the insertion of each screw. If the drill point is too large in relation to the root diameter, the threads will be shallow and the holding power will be decreased proportionately. It is apparent, therefore, that the optimum diameter of the drill point is constant for a screw of a certain size.

In order to correct the above deficiencies, a drill point has been made of 18–8 SMo—the same material, but slightly harder than the plates and screws—with a diameter of 0.110 inch (No. 35), which is considered the optimum size for the screw in question (Fig. 3, *B*). This drill point can be bent, but is unbreakable. The length is distinctive, so that it will not be confused with other drill points of approximately the same size. The spiral is long enough to permit drilling the cortex, and yet not long enough to enlarge the hole in the proximal cortex as the distal cortex is drilled. The relief, or small ledge, found on standard drill flutes is also omitted in this drill point.

NEW PLATES

In order to simplify the manufacture and supply of plates, six sizes have been adopted, since these include all the essential lengths previously provided in eleven sizes.

The design of the Sherman plate has been modified (Fig. 1) by increasing the width of the mid-section to the maximum width of the plate at the screw holes. This change increases the strength and rigidity of this section, which spans the fracture site, by approximately two and one-half times that of the former plate of the same composition and hardness. Comparison of the bending moment of the two plates showed a ratio of 11 to 28, in favor of the new plate, in producing a deflection of 0.010 inch under similar conditions. Since the physical properties of this metal are constant, the strength of the plate at any point is in direct relation to the dimensions and shape of the cross section. This plate is very strong and rigid, but can still be bent as required by bending irons. The design is not original, since it is similar to that previously adopted in Canada. The Canadian plate is made of a different alloy, however (the hardness was Rockwell C-12 to C-21 on the sample

of the roots. Therefore, in these patients the operation has consisted of a laminectomy, intervertebral foraminotomy, and surgical fusion. The foraminotomy is performed on the side of the sciatic pain; in patients with pain in both legs, a bilateral foraminotomy is performed. Of the nine cases in which intervertebral foraminotomy was performed, four operations were bilateral, two were on the right, and three on the left side. The operative technique is well illustrated by the following case:

F. G., a white female factory worker, aged twenty-two, came to the Clinic for relief of a disabling backache of twelve years' duration. Following a fall while roller-skating eight months previously, the backache had become more persistent and pain radiated into both buttocks. There was frequent numbness in both feet, and coughing initiated stabbing pains in both buttocks. Examination revealed increased lumbar lordosis and undue prominence of the fifth lumbar spine, which was tender to digital pressure. The patellar and tendo calcaneus reflexes were normal. There were no changes in perception to pinprick or to a light touch. There was some atrophy of the left calf. Anteroposterior and lateral roentgenograms disclosed a defect in the neural arch of the fifth lumbar vertebra, diminished transverse diameter and posterior wedging of the vertebra, and forward displacement of the fifth lumbar vertebra on the sacrum. A diagnosis of spondylolisthesis was evident. Because of the long history of backache, and the severity of the pain, which had disabled the patient so that she had been unable to work for several months, an operation was recommended.

Through the customary mid-line incision, the laminae of the fourth and fifth lumbar vertebrae and the sacrum were exposed in the usual manner. The lamina of the fifth lumbar vertebra was noticeably loose, and was not fused with its pedicle. This lamina was split in the mid-line and completely removed by carefully reflecting the epidural tissue from its surface. A thorough examination was then made for the oppressing medium causing the sciatic pain, by probing the course of the nerve roots. There was no evidence of any pressure by a pathological intervertebral disc. The first sacral nerve root was explored as it passed through its foramina; these channels were definitely narrowed in caliber. The left root appeared to be angulated and compressed over the posterior aspect of the body of the first sacral segment. The roof of this foramen was carefully removed with a sharp osteotome and curette, whereupon the nerve root seemed to bulge out and expand. The pedicle and the facet were then thoroughly curetted and gouged out. On the right side, a similar unroofing of the foramen was accomplished, and the superior rim of the bony border of the sacral foramen was removed. The nerve root then appeared to be taking a more direct route outward. The exposed roots were covered with fat, and a chip fusion was performed in the routine manner, care being exerted to cover the area of the exposed dura and roots with rather small, flat bone chips. Convalescence was uneventful, and the patient followed the usual postoperative routine. She was discharged from the Hospital on the forty-third day after operation, symptom-free, wearing a low-back support. The patient returned to her factory work seven months after the operation. She has been followed in the Clinic at three-month intervals for two years since the operation, has remained symptom free, and has been able to continue her usual occupational activities.

RESULTS

All of the patients in the series have been followed for periods ranging from three months to sixty-six months after operation. These patients have been examined regularly at short intervals during this time by the senior author. Certain definite conclusions can be drawn from an analysis of each individual patient as he returned to normal routine activities after the operation.

In the first group of patients—those who presented uncomplicated low-back pain and who were subjected to a technique of laminectomy followed by a chip fusion—the results were as follows:

Case 1. H. B., a factory foreman, who had had pain in his back for ten years before operation, was last seen sixty-six months after the operation. He stated that his pain had been entirely relieved, that he was working without a brace, and that he felt very pleased with the result obtained.

Case 2. J. G., a practical nurse, was last examined eighteen months after operation, and at that time she reported a complete absence of pain in the lower part of the back; she did have a feeling of weakness in the left leg, however. She had found steady employment as a nurse, and had discarded her back support several months before.

Case 3. J. S., a factory worker, when last interviewed forty-four months after operation, was employed in a factory, lifting heavy cans, and had no pain of any consequence.

Case 4. D. D., who was examined forty-three months after operation, stated that she was able to do her housework without pain and without benefit of a low-back support.

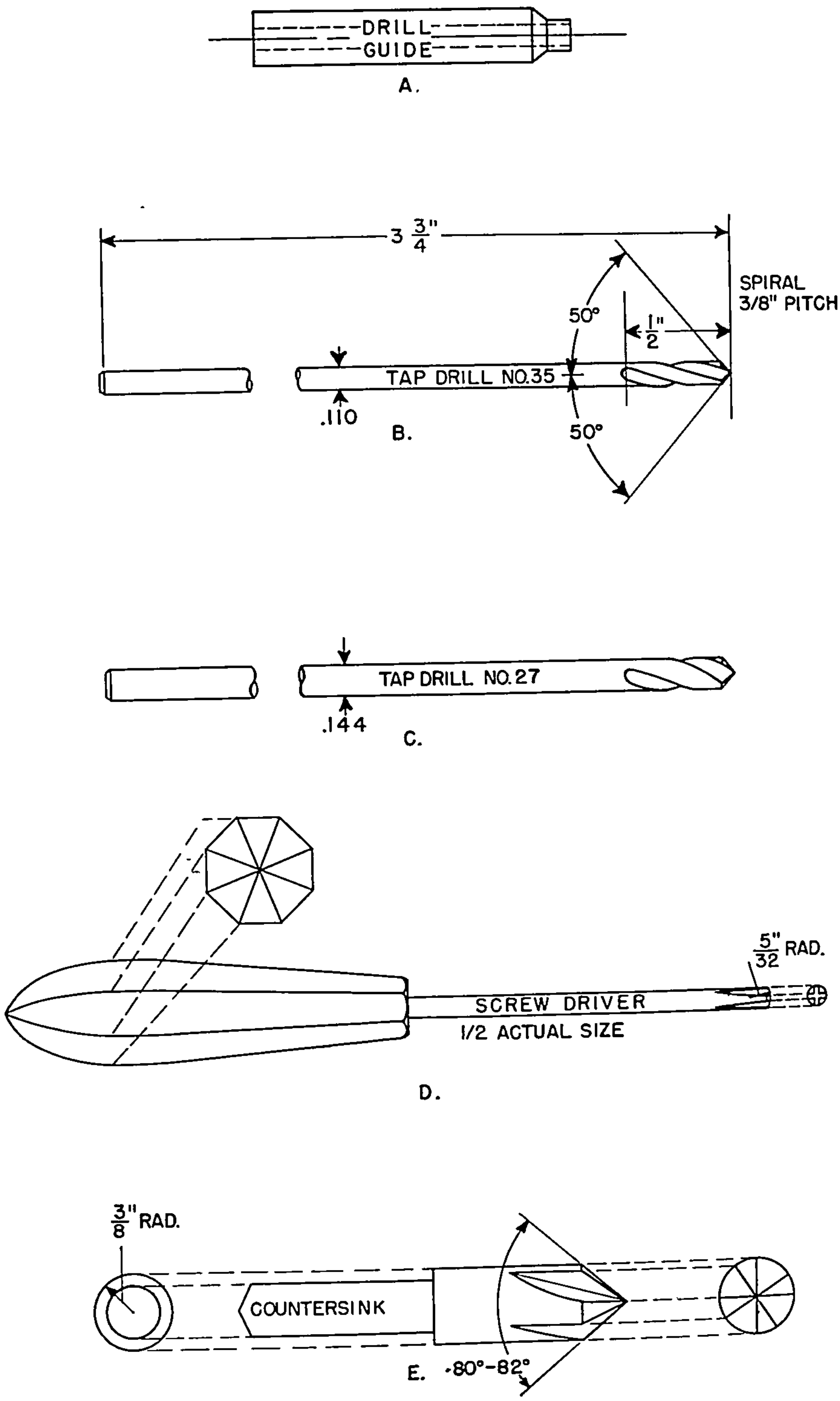


FIG. 3

Shows equipment for application of plates and screws.
A: Drill guide for proper centering of hole in relation to the plate.
B: Drill of proper size for self-tapping screws, shown in Fig. 2.
C: Drill slightly larger than outside diameter of screw, to be used in proximal cortex when the threads do not engage this cortex.
D: Screw driver for the cruciate head.
E: Countersink. The point has the same taper as the screw head, and permits it to be inserted deeper into the bone.

of thread for fixation. The value of flutes has been controversial, but they are considered essential for proper thread cutting. The flutes described will readily cut thread in the maximum thickness of cortex encountered in man. If an unusually thick cortex is encountered, as in a laboratory trial with heavy animal bone, the flutes become filled with

able to do all of her heavy housework without pain in the back or legs, and had long since discarded her support.

CASE 11. S. A., a house painter, was subjected to a bilateral foraminotomy, followed by fusion. When seen, four months later, he was entirely relieved of the pain in the back and legs, but had occasional feelings of weakness and vertigo. He was still wearing his brace.

CASE 12. W. B., a carpenter, who had had a bilateral foraminotomy, was last seen thirteen months after the operation. He reported that he was able to do a full day's work without pain, and that he had discarded his brace.

CASE 13. E. E., a laborer, was relieved of pain by a bilateral foraminotomy. He has not been followed regularly, but when last heard from, some months after the operation, he was back at work.

CASE 14. C. G. was subjected to a foraminotomy and fusion of the left fifth lumbar vertebra. Although his leg pain was relieved, he had persistent low-back pain. Roentgenograms showed an incomplete fusion with pseudarthrosis between the fourth and fifth lumbar vertebrae. A revision of the graft was performed, and the patient was soon able to return to work and was free of pain.

CASE 15. F. W., a clerk, forty-seven years old, was relieved of her leg pain by excision of a protruding fifth lumbar disc and a partial foraminotomy. Because of the patient's poor condition during the operation, it was not possible to do an adequate fusion. She has been relieved of her leg pain, however, and is scheduled to return for a fusion of the involved segments.

CASE 16. G. N., a mason, who had suffered from backache for fifteen years and presented a "double subluxation" of the bodies of the lumbar vertebrae, had a foraminotomy at both the fourth and fifth lumbar foramina on the left side, followed by fusion. He has not had a recurrence of the disabling leg pain or backache in the eleven months since the operation.

CASE 17. E. W., a sixteen-year-old schoolgirl, presented an unusual deformity. Roentgenograms revealed a complete subluxation of the fifth lumbar vertebra, with the body of this vertebra reposed anterior to the sacrum. The patient had suffered from severe backaches for two years, and had excruciating pain of right sciatic radiation. A foraminotomy was performed and the first sacral nerve root was decompressed. A fusion was not performed at the time, because of the patient's poor condition. She had some difficulty with bladder control after the operation, but has had complete relief of the backache and leg pain. She was discharged six weeks after the operation without pain and wearing no brace. When examined three months after the operation, the patient was asymptomatic, bladder control had returned, and she was attending school regularly.

CASE 18. F. G., a young factory worker, presented severe bilateral leg pain of sciatic radiation. She was subjected to a bilateral foraminotomy and fusion. When seen thirteen months after the operation, she complained of only occasional backache. The leg pain had been entirely relieved, and she was working regularly.

DISCUSSION

The relief, by operative measures, of backache and sciatic pain associated with spondylolisthesis poses several interesting problems. Although there have been no accurate descriptions of the mechanism of the backache connected with this deformity, most observers are satisfied that the instability of the involved vertebral segments is the basic factor behind the associated low-back pain. It is generally accepted that immobilization of these segments by a surgical fusion is essential for the relief of the pain; and many such methods of fusion, through both anterior and posterior approaches, have been proposed. A modified chip fusion, as described by the senior author, the iliac crests being used to augment the mass of bone when necessary, has proved a most satisfactory procedure. By careful application of the bone chips to the prepared pedicle base, a firm anchor to the anterior segments of the defect is obtained. In addition, a large quantity of bone chips can be placed over the exposed dura and nerve roots with relative impunity, if they are first covered with muscle or fat.

The mechanism of the leg pain associated with spondylolisthesis is not clear. Pressure on nerve roots by protrusion of intervertebral discs as a cause of sciatic pain must be recognized. In only one of the nine patients presenting severe leg pain was the finding made of clear-cut oppression of a root by a protruding intervertebral disc. In the remaining cases, definite pathological changes in the intervertebral foramina probably accounted for the leg pain. We are not in a position as yet to place the guilt definitely either on a

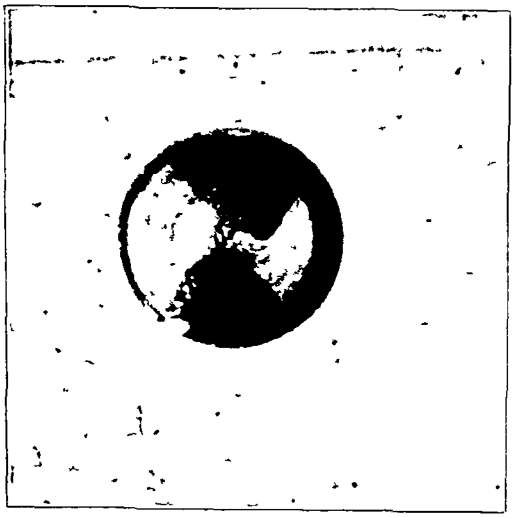


FIG. 6

FIG. 7

FIG. 6: The succeeding illustrations were prepared with the use of a specimen of dried beef bone, measuring nearly one-half inch in thickness, to show details of screw fixation. In this illustration the tip of the screw, properly centered in the drill hole, is shown emerging from the bone. (*Negative No. 98151, Army Institute of Pathology.*)

FIG. 7: The tip of the screw, improperly centered, is shown emerging from the bone at an angle. Note that the screw does not engage the bone on one side, while it is breaking the bone away on the opposite side, where it is forced too deep beyond the drill hole. (*Negative No. 98150, Army Institute of Pathology.*)

tend to tap and seat itself in line with the drill hole, and will not be forced out of line, as happens with angulation of a rigid screw-holding driver.

An optional feature, known as the pilot point, has been provided in the screws. The distal two or two and one-half threads are reduced to the size of a No. 35 drill (0.110 inch), or the exact size of the hole in the bone. This has the advantage of permitting the placement of the screw in the bone without a holding device, in preparation for its further insertion. It has the further advantage of starting the screw in the proper direction, so that it will follow the center of the proximal hole and hit the center of the hole in the distal cortex. This avoids the common error of hitting the distal hole eccentrically and thereby forcing the screw into line under pressure, with resulting strain and damage to the threads (Figs. 5, *A* and *B*, and 11). In the pilot point the reduced threads do not, of course, engage the bone; and this length of the screw is not effective, except as the point may help stabilize the screw where it passes into, but not through, the distal cortex. Where the distal cortex is completely engaged by the threaded portion of the screw, the point must project beyond the cortex approximately one-sixteenth of an inch farther than with the conventional screw; and allowance must be made for this extra length in the selection of a screw. If the length of screw is accurately determined by a depth gauge, the advantages of the pilot point more than compensate for this slight additional length. However, fixation, such as that illustrated in Figure 5, *C*, is entirely adequate. Incidentally, the difference between the diameter of the full thread and the reduced thread on the pilot point is the depth of thread engaged in the bone (Figs. 10 and 12).

TABLE III

REPORT OF TWELVE ARMY HOSPITALS ON THE USE OF THE NEW-TYPE STEEL SCREW

Questions Included	Yes	Indifferent or No Reply	No
Is the cruciate slotted head suitable and efficient?	12		
Does the self-tapping property of the screw make it superior to the standard?	8	4	
Is the pilot point adequate and of sufficient length?	10	1	1
Is the No. 35 drill adequate and superior to the No. 32 drill?	11	1	
Is the cruciate screw driver adequate and efficient?	11	1	
Is the centering device necessary and desirable?	6	6*	

* Because of lack of complete technical information on the use of this device, these hospitals did not report.

FIXATION OF BONES BY PLATES AND SCREWS

BY LEONARD T. PETERSON*, M.D., WASHINGTON, D. C.

Internal fixation of bones by plates and screws depends for its success upon suitable materials and proper operative technique. During World War II, the Office of The Surgeon General endeavored to have improved bone plates and screws developed. In this endeavor, a number of individuals and agencies played a part, notably the National Bureau of Standards, whose scientists conducted extensive experiments on the strength and quality of materials and on the holding power of screws in bone. They examined and tested over twenty bone plates and screws which had had to be removed from patients in Army hospitals because of failure, either by bending or breaking, in some instances associated with corrosion of the plates or screws. It is the purpose of this paper to outline briefly the background for and the present status of this development with special reference to the clinical application of new designs, tentatively adopted under Army specifications. The present design of plates and screws is based on mechanical principles, and is supported by a short period of clinical trial in a number of Army hospitals. Further clinical experience will be of value in the preparation of a new commercial standard to supersede Commercial Standard CS 37–31, dated March 23, 1932. Since the tentative Army specifications will probably influence the manufacturing and procurement of plates and screws, this information is of interest both to the medical profession and to the manufacturer. It is hoped that it will contribute to the adoption of more uniform standards in material and design.

Metal used in the fixation of bones should possess certain chemical properties which will not result in physiological disturbances in the body. It is not the purpose of this paper to discuss the chemistry of the various alloys. Before the War, the Army adopted as a standard the steel known as 18–8 SMo, because it is inert in body tissue, is superior in strength, is constant in composition, and possesses physical properties which make it resistant to fatigue and breakage. The designation 18–8 SMo (sometimes incorrectly written as S-M-O) is applied to a range of high-alloy stainless steels with a chromium content of approximately 18 per cent. (ranging from about 15 to 19 per cent.), a nickel content of approximately 8 per cent. (ranging from about 8 to 14 per cent.), and a molybdenum content of about 2 to 4 per cent. The molybdenum increases the strength of the alloy and its resistance to corrosion. Other elements are within certain prescribed limits.

To prevent electrolytic action between screws and plates, it is necessary to specify even narrower limits of these alloying elements, and to limit the amount of certain impurities. Extensive investigations have shown that an alloy meeting the specifications given in Table I has adequate strength, and will ensure against harmful corrosion by the body fluids, provided it is cold-worked to meet the hardness specification. It can be seen from Table I that the formula specified for plates and screws would be more correctly expressed as 18–12 SMo, since the content of nickel is limited to 10 to 14 per cent., but the general term 18–8 is still used. Steel designated as 18–8 stainless, but without Mo, is not of the same composition, is inferior to SMo for this purpose, and should not be used in conjunction with SMo. The superior chemical and physical qualities of the 18–8 SMo for internal fixation were confirmed in a report published in 1945 by the Subcommittee on Bone Plates and Screws of the Committee on Fractures and Other Traumas, American College of Surgeons[1].

The importance of the proper chemical composition to render metal inert in the body has, in recent years, overshadowed the existing need for improved designs and for new and more rigid specifications in the manufacturing of plates and screws. Consequently, many

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FIG 11

FIG 12

Fig 11 This hole was purposely drilled eccentric to the hole in the overlying plate The screw was then inserted until the head was forced into the countersink, thus forcing the screw laterally, as illustrated in Fig 4, *F* Note that the first three threads are stripped,—the first almost completely and the third only slightly There are only eight threads, because the screw used was only one-quarter inch long (*Negative No 98142, Army Institute of Pathology*)

Fig 12 The screw was inserted only part way through the cortex, to show the relation of threaded to unthreaded portion of the drill hole. (*Negative No 98144, Army Institute of Pathology*)

The new type of cruciate-headed screw was sent to a number of Army hospitals in March 1946, along with the drill point, drill guide, and screw driver. Twelve hospitals have reported on these items, on the basis of their clinical application by a considerably larger number of surgeons. The replies to a questionnaire are reported in Table III. One additional hospital reported, but the report was discarded as unsatisfactory. Since that time the screws have been supplied to a number of civilian surgeons and institutions, with equally good results While these opinions are not based on a long period of follow-up of the individual cases, which is difficult to obtain under military conditions, the evaluation of both the screws and the plates can be determined quite satisfactorily on mechanical principles and by laboratory tests, as well as by clinical experience.

TECHNIQUE

Brief mention has already been made of some aspects of operative technique, in connection with the design of plates and screws. For the proper application of these devices, the following additional technical points should also be observed:

The plate should conform to the shape of the bone, and any inequality should be adjusted by accurate shaping of the plate before it is fixed. It is obviously not good technique for the screws to bend a plate to fit the bone, since in so doing a spring action results and the screw is immediately subjected to a strong pulling-out force. The screw should fit in the center of the hole in the plate, so that the head of the screw will have uniform contact and pressure on the plate. If the screw is not properly centered, as it is tightened there will be a tendency for the countersink in the plate to force it to one side, thereby damaging the

For good internal fixation, there must be a close correlation between the holes in the plates, the diameter of the drill point, and the root and major diameter of the screw.

2. *Poor Thread-Cutting Qualities of the Screw*: Flutes in self-tapping screws have in many cases been little more than grooves or notches, with little or no tapping quality. Many screws furnished the Army by one large manufacturer had very defective flutes, inasmuch as the metal cut from the flutes had accumulated in the threads, thereby rendering the screws unfit to properly cut thread in the bone. The flutes have often been unnecessarily long and wide, thereby sacrificing much of the thread and reducing the holding power of the distal end of the screw.

3. *Improper Design of the Head*: The standard slotted head is inadequate and does not furnish firm enough anchorage for a screw driver, causing the screw driver to slip out of place and to damage the head. This is particularly troublesome in the removal of screws which are tight. Self-retaining screw drivers are often not exact enough to allow the screw to follow its proper course, and are of no value in the final turns on insertion or in the initial turns at the time of removal of the screw. The Phillips recessed head, which has proved very popular in industry, cannot be produced economically in 18–8 SMo because of the hardness of this steel. The screw head to be described here is made by a different process, and has been developed to meet this difficulty. The taper of the head should be of proper shape to match the corresponding shape of the countersink in the plate. Wide variations have existed in these dimensions.

In discussing the design of the screw, the coarseness of the thread (threads per inch) must be considered. There is a common belief, as yet neither proved nor disproved, that coarse thread—for example, eighteen per inch—has better holding power in bone than fine thread, such as thirty-two per inch. Extensive tests on cortical, as well as cancellous, portions of fresh animal bones under carefully controlled conditions failed to show any significant difference in the initial holding power of screws with fine and coarse threads in each type of bone. In these tests, the Bureau of Standards designed a torque meter to measure the force required for the insertion of screws. Holes were drilled under mechanical control, and the holding power was tested by a standard pulling machine. As far as is known, the relative holding power of different threads has not been determined in living bones under conditions of a constant known pulling force. Successful preliminary tests of this nature have been conducted in animals, and further experimental work is contemplated. At a later date it may be necessary to revise the specifications for threads, but at present, for lack of evidence to the contrary, the Army has elected to continue the use of fine-threaded screws (thirty-two per inch) which is the commercial standard thread for the diameter involved.

DRILL POINTS

A discussion of screws and plates would not be complete without reference to drill points. The quality of the ordinary steel drill points, commonly used in bone surgery, has been such that drills have frequently broken, thereby preventing the proper insertion of a screw and often necessitating leaving a fragment of drill in place. The fact that a fragment is left means that dissimilar metals are present and an electrolytic reaction is established.

Another difficulty is that of selecting a drill of the proper size. The size is usually difficult to read, and the relation between the size of the drill point and the particular screw to be used may be unknown to the surgeon or the operating-room personnel. The size of the drill point must be somewhere between the root diameter and the maximum diameter of the screw. If it is equal to or less than the root diameter, extreme force will be required for insertion of the screws, and undesirable pressure will probably result. If the diameter of the drill point equals the root diameter of the screw, it is probably desirable to pretap the thread. This would give the maximum depth of thread, but this procedure

FIG. 15

The flutes were cleaned twice during the insertion of this screw. This made the screw turn more easily than in Fig. 13, but the threads are similar to those in the two preceding illustrations. The first threads were not injured by repeated removal and reinsertion. (*Negative No. 98152, Army Institute of Pathology.*)

The drill point should be turned without describing an arc, which tends to enlarge the hole. The hand drill wobbles unless it is held very accurately. The motor drill possesses certain advantages, since its power is mechanical and the operator can devote his attention to direction. One other important factor should receive his attention while he uses the electric drill, and that is the rate of drilling. If the drill is thrust through the bone at a high speed, especially if the drill is dull, it will burn the bone and produce necrosis (Fig. 8). A slow rate of speed is desired, because it avoids unnecessary bone damage (Fig. 9) and, furthermore, it is safer for the patient and the operator. Sufficient reference has already been made to proper drill size, and of course the drill point must be sharp and absolutely straight. If proper technique is used and if the materials are of good quality, threads will be cut so accurately and sharply that the screw can be removed and reinserted easily in the same hole without lessening its efficiency (Figs. 14 and 15). With this technique, no force is required to push the screw in, and the force is all directed at turning the screw.

It is commonly believed that all screws which engage a plate should engage both cortices. It is not the purpose of this paper to settle that point, but with improved devices and technique we may find that it is not necessary for all the screws to be long. Where short screws are used in the proximal cortex only, pilot-point screws are advised, because of the ease of insertion without a holding device and because there is no disadvantage in length, since the pilot point remains inside the bone. Where long screws are used to engage both cortices, pilot-point screws are advised, because the point also tends to direct the screw to the center of the distal hole. As stated previously, allowance must be made for the pilot point in selecting the proper length of screw, if threads are to completely engage the distal cortex.

In some cases it is desirable for the threads to engage the distal, but not the proximal, cortex. This can be done with a screw which has a non-threaded segment just distal to the head. However, the same objective can be attained with the standard screw by merely enlarging the proximal hole with a No. 27 drill of 0.144 inch diameter (Fig. 3, *C*), which exceeds the maximum diameter of the screw and permits the threads to pass freely through this hole, as illustrated in Figure 5, *D* and *F*. In this instance, the whole screw acts as a pilot point and the non-pilot-point screw is satisfactory, although the pilot point possesses no disadvantage, except for the slightly greater length (one-sixteenth of an inch) required. In placing a screw through two fragments, as in an oblique fracture, with or without the use of a plate, this method of engaging only the distal cortex tends to draw the two fragments firmly together. If both cortices are tapped, the screw fixes but does not impact the

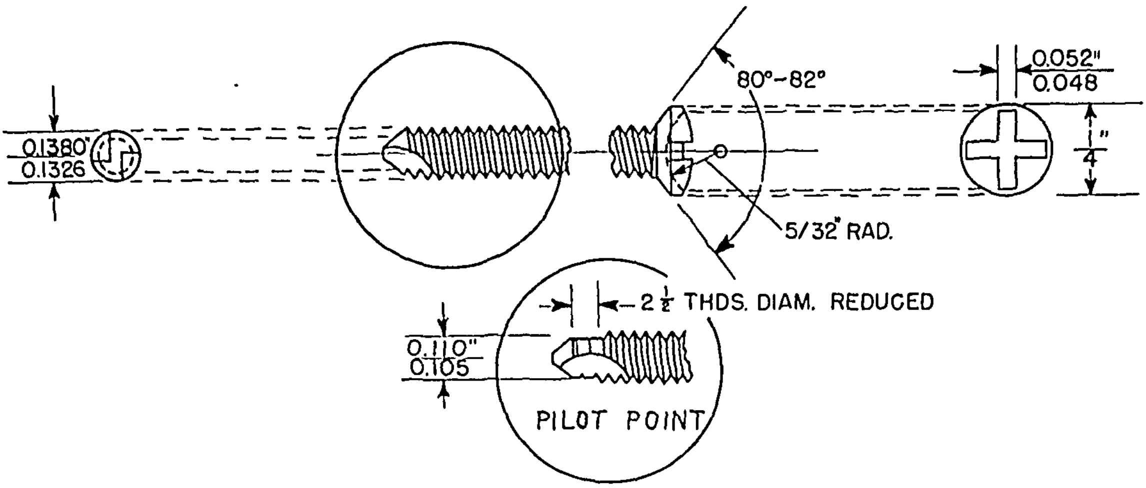

Fig. 2

Details of screw with cruciate head and improved cutting flutes. Inset shows pilot point, reduced to the diameter of the drill. (Complete specifications include some details not shown.)

tested), and the plate is, therefore, considerably larger and heavier than the plate made of 18–8 SMo of the specified hardness.

The thickness of the individual plate is uniform throughout. The length of the midsection is limited to one and three-eighths inches in the longest plate, whereas it was formerly two and five thirty-seconds inches in the No. 0 plate. If the edges of the plate do not bear on the surface of the bone, it can rock sideways on the bone, even when screwed tightly to it. This produces varying bending stresses in the screws, which can cause them to fail by fatigue. Some of the broken screws examined at the National Bureau of Standards showed failure, typical of fatigue in bending. For that reason the radius of curvature of the plate should be smaller than the radius of curvature of the bone to be plated, to ensure that the edges of the plate bear on the surface of the bone. Some plates examined had radii as great as one inch, although three-eighths of an inch was specified. A radius of three-eighths of an inch, the same as previously, is specified for the four larger plates. For the two smaller plates, one-quarter inch is specified, to adapt them to the smaller bones on which they are used. The size of the holes and the angle and depth of the countersink have been specified with exact tolerances, as illustrated.

NEW SCREWS

In order to correct existing faults in screws, exact dimensions and tolerances have been established for the major diameter, root diameter, threads, flutes, and head (Fig. 2). The flutes, two in number, are short, deep, and of excellent cutting quality; they displace only one-half the area of the two distal threads, thereby preserving the maximum amount

TABLE II

Specifications for New Plates

New Size	Old-Style Plate of Same Length	Length (±*1/16 Inch*)	Thickness (±*0.015 Inch*)	No. of Holes	Maximum Width (±*0.015 Inch*)	Width Between Holes (±*0.015 Inch*)	Radius (*Inches*)
A	00,0	5 9/32	0.095	6	0.406	0.260	3/8
B	1, 2, 3	4 19/32	0.095	6	0.406	0.215	3/8
C	4	3 21/32	0.065	4	0.375	0.146	3/8
D	5, 6, 6½ (Approximately)	3 1/6	0.065	4	0.375	0.146	[illegible]
E	7	2.227	0.065	4	0.336	0.125	1/4
F	8	1.960	0.065	4	0.336	0.125	1/4

ARTHROPLASTY OF THE ELBOW BY REPLACEMENT OF THE DISTAL PORTION OF THE HUMERUS WITH AN ACRYLIC PROSTHESIS

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From the Orthopaedic Surgery Section, O'Reilly General Hospital, Springfield, Missouri

A review of the literature for the past ten years has failed to reveal the use of plastic material, such as lucite, in arthroplasties or reconstructions of the elbow joint. For quite a number of years lucite, in the form of cups, has been employed for arthroplasties of the hip. Recently its use has been reported by Burman and Abrahamson as an interposition substance in arthroplasties of the interphalangeal and metacarpophalangeal joints. At O'Reilly General Hospital, the authors have used plastic material independently in the metacarpophalangeal joints in quite a number of cases. The results have been no more outstanding than those obtained from standard methods of arthroplasty.

As a satisfactory method for replacement of a large defect involving the distal part of the humerus and the proximal portion

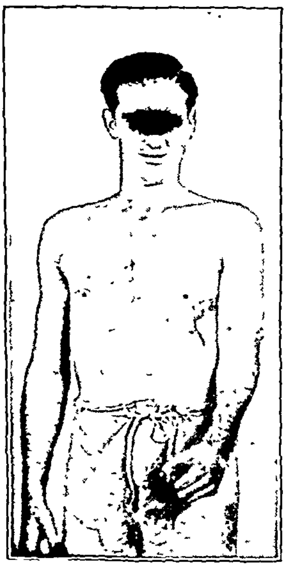

FIG. 1-A

FIG. 1-B

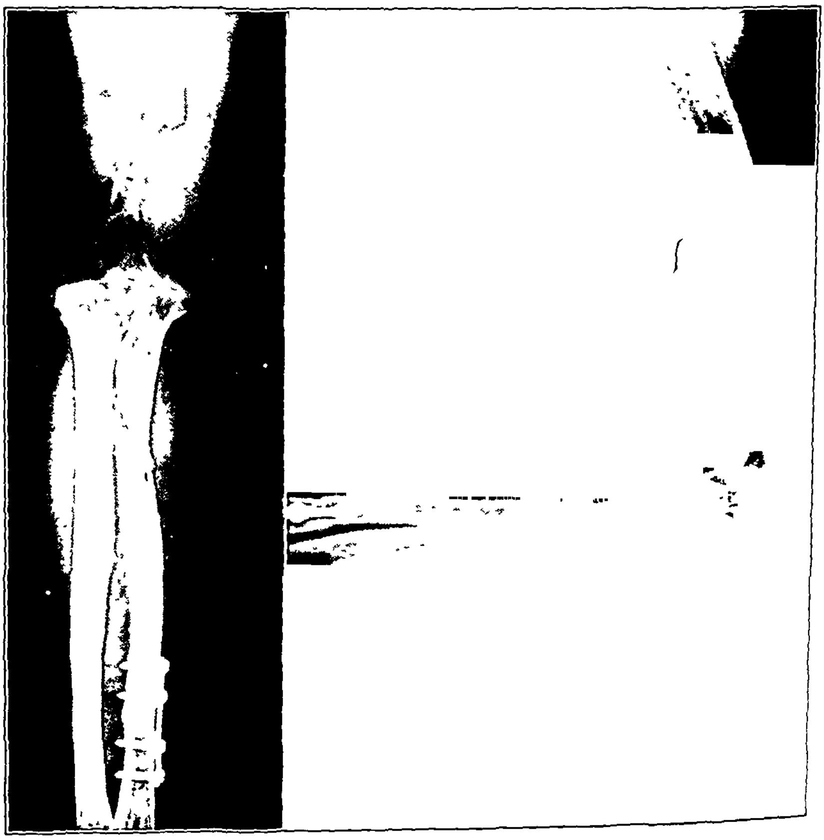

FIG. 1-C

Fig. 1-A: Case 1. Shows the amount of active flexion in the left elbow, ten months after injury. The distal third of the humerus and the olecranon process of the ulna had been removed at the time of the initial débridement.

Fig. 1-B: After attachment of an acrylic implant, four and one-half inches long, onto the distal end of the humerus, the patient was able actively to flex the left elbow to 90 degrees; and stability in the joint was much improved.

Fig. 1-C: Anteroposterior and lateral roentgenograms of the left elbow region, ten months after injury. There is loss of the distal five inches of the humerus, as well as of the olecranon process of the ulna.

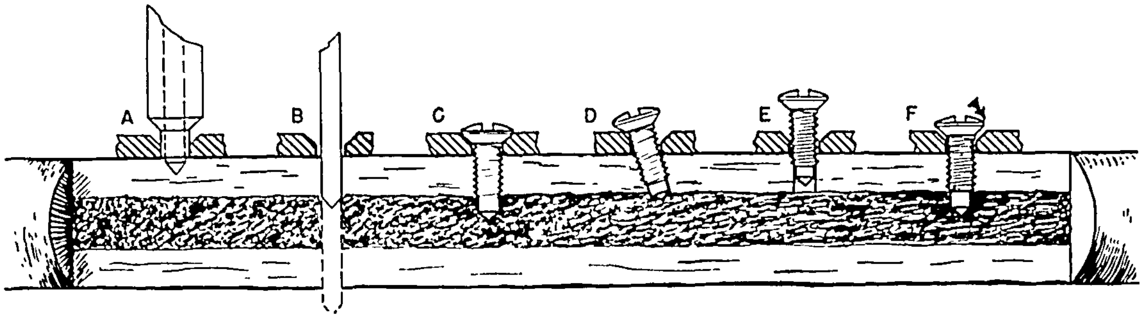

Fig. 4

Technique employed in plate fixation.

A: The use of the drill guide ensures the proper centering of the screw in relation to the hole in the plate.
B: After the hole has been started, the guide is removed, and the hole is drilled through one or both cortices. If the guide is kept in place, it will tend to become filled with bone chips.
C: A screw, properly centered and perpendicular to the plate. The head of the screw fits the countersink accurately.
D: A screw inserted at an angle. The threads are likely to be damaged by the edge of the plate. The head comes into contact with the plate at only one point, instead of uniformly, as in *C*.
E: A screw inserted perpendicularly, but eccentric to the hole in the plate. This is common if a drill guide is not employed. The threads are likely to be damaged if sufficiently eccentric, since the clearance between screw and plate is only from 0.009 to 0.020 inch.
F: As the screw in *E* is tightened, the head will be forced into the countersink in the plate. This lateral force on the screw tends to cause excess pressure and to strip the threads already cut in the bone, as illustrated in Fig. 11.

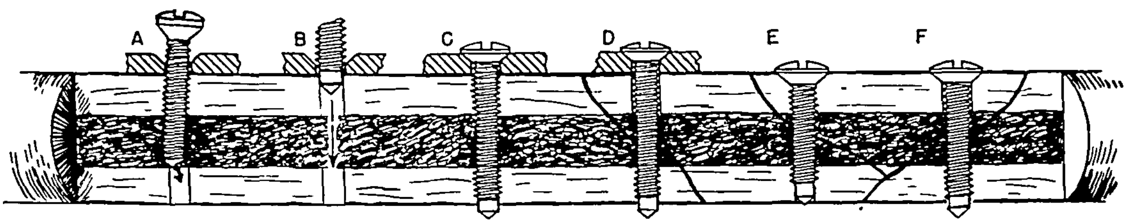

Fig. 5

Technique in plate and screw fixation.

A: A long screw without pilot point has been inserted at a slight angle in relation to the drill hole. This is common in actual practice. The point may completely miss the hole or it may hit it eccentrically. Then, as it is forced into line, it will tend to strip the threads already cut in the proximal cortex.
B: A screw with the pilot point. The tip accurately fits the drill hole and tends to direct the screw properly. Furthermore, it holds the screw, so that it may be more easily controlled without the use of a screw-holding device on the screw driver. A longer pilot point would be more effective for both purposes, but this portion of the screw does not engage the bone.
C: A long pilot-point screw, properly centered and of optimum length.
D: After both cortices have been drilled with a No. 35 drill, the hole in the proximal cortex has been enlarged by a No. 27 drill (0.144 inch) so that the threads engage only the distal cortex. In this case the whole screw acts as a pilot point. This method makes possible the impaction of fragments when the screw is tightened.
E: Two fragments of bone, fixed with a screw without use of a plate. The hole in the proximal cortex has been countersunk (Fig. 3, *E*). This avoids the tendency for the tapered head to split the bone, and also makes the head less prominent.
F: The proximal hole has been both enlarged as in *D*, and countersunk as in *E*, and permits impaction of the fragments. Methods *E* and *F* are applicable in fixation of fragments and of onlay bone grafts.

bone after cutting part way; and insertion of the screw becomes increasingly difficult beyond this point. If the screw is then withdrawn, cleaned, and reinserted, the remaining bone will be tapped as easily as the first portion. This demonstrates the value of flutes of good quality.

The cruciate type of screw head illustrated in Figure 2, designed by Mr. J. G. Collison, provides firm anchorage for the screw driver, possesses advantages similar to the Phillips head, and does not require a screw-holding device. The cruciate slots in the head describe the same arc as the point of the screw driver (Fig. 3, *D*). Therefore, angulation of the screw driver results in a universal-joint action with the screw head; and the screw will

acrylic prosthesis, measuring four and one-half inches in length, was attached to the distal end of the humeral shaft with two loops of No. 20 tantalum wire. The postoperative course was uneventful, except for a transient incomplete palsy of the radial nerve, which completely subsided in three weeks. After removal of the skin sutures on the tenth day after operation, the patient was encouraged to use the left arm; and within six weeks he was able to flex the elbow actively to a right angle. He was able to use his hand better, and could raise it approximately to his mouth. There was considerable instability of the elbow joint, but much less than before operation. He was still unable to use the hand for any work above the level of his shoulder. The soldier was discharged from the Army on a certificate of disability on November 28, 1945, and at this time he was still unable to flex the elbow actively to more than 90 degrees (Fig. 1-B). There was no pain in the elbow, and no evidence of any irritation about the acrylic implant (Fig. 1-D).

A similar problem presented itself in several cases of non-union in the supracondylar region of the humerus. In these cases the distal fragment of the humerus was malunited, and the elbow joint was fixed by fibrous ankylosis. This mitigated against the restoration of any satisfactory painless motion in the elbow itself after bone-grafting of the humerus,

Fig. 2-A

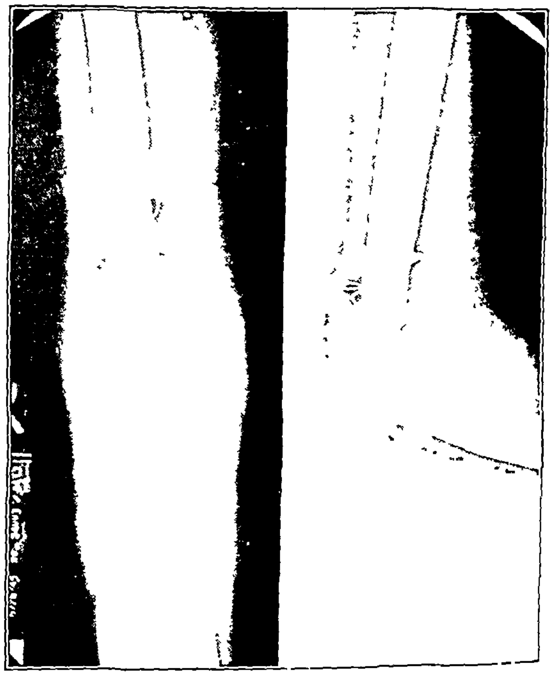

Fig. 2-B

Fig. 2-A: Case 2. Anteroposterior and lateral roentgenograms of the right elbow, showing non-union of the comminuted supracondylar fracture and narrowing of the joint space.

Fig. 2-B: Anteroposterior and lateral roentgenograms of the right elbow, one month after replacement of the ununited distal end of the humerus by an acrylic implant. The prosthesis was attached to the humerus by two loops of tantalum wire. The tip of the olecranon has been resected.

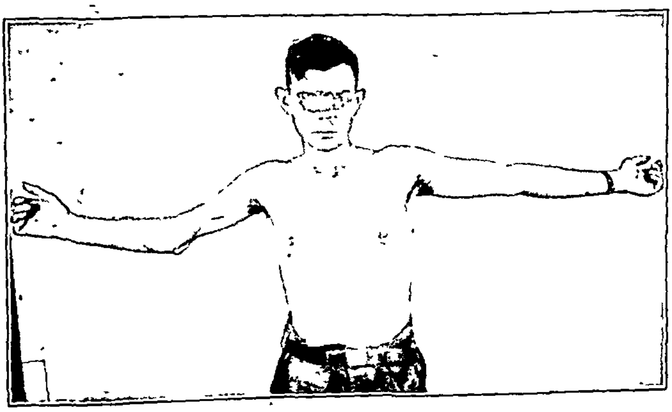

Fig. 2-C

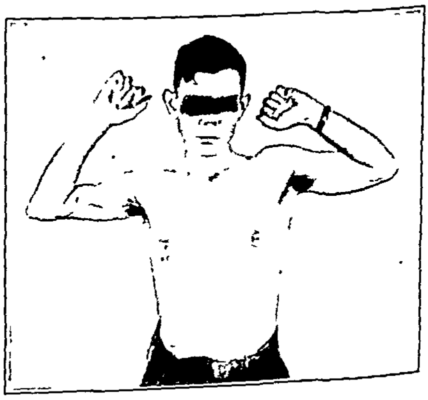

Fig. 2-D

Photographs, taken five months after insertion of an acrylic implant in the right elbow, show range of active elbow motion. Stability of the elbow joint was excellent.

FIG. 8

FIG 9

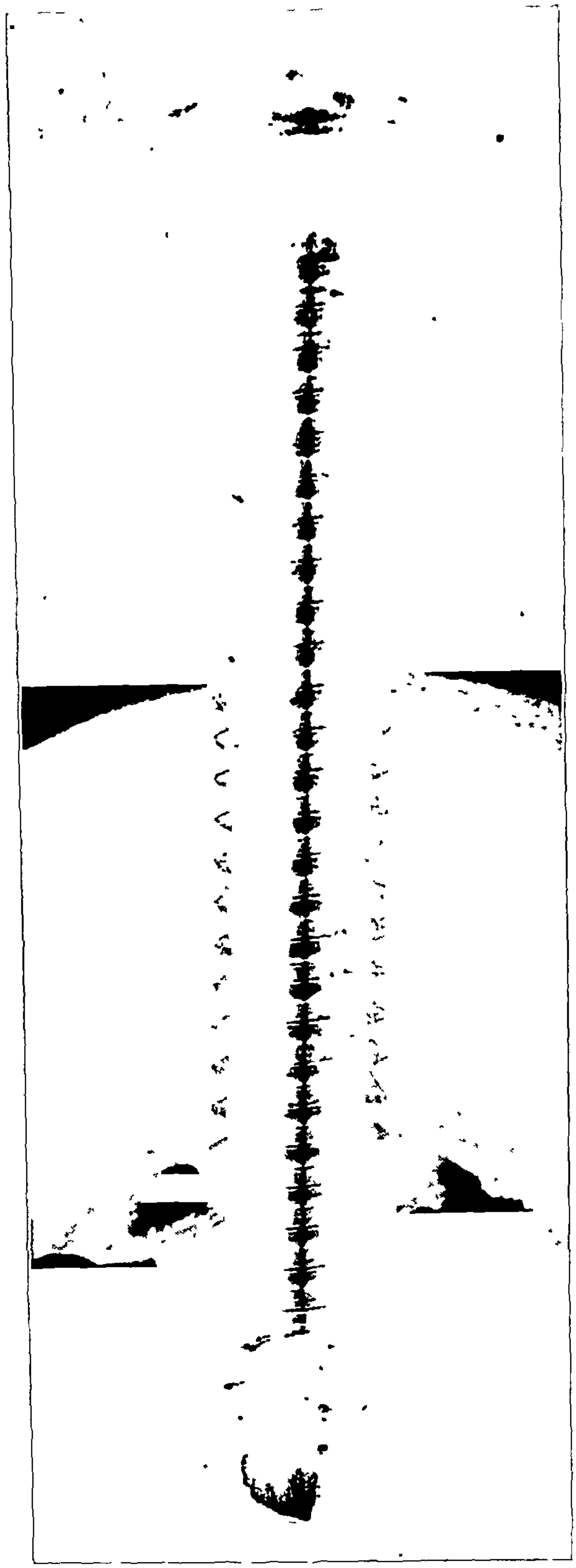

FIG. 10

Fig. 8: This hole was drilled with a dull drill point and the electric motor at high speed. The screw was then inserted at an angle, as in Fig. 7. Note the marked fragmentation and discoloration of the threads, due to overheating. Note also the gradual disappearance of threads in the center, whereas threads were cut on the other half of the specimen (not shown) due to angulation of the screw. Poor fixation would result. (*Negative No. 98146. Army Institute of Pathology.*)

Fig. 9: This hole was drilled with a sharp drill point and the electric motor at moderately high speed, which did not overheat the bone. Note the sharp outline of the threads and absence of discoloration. The screw was again purposely inserted at an angle; the gradual disappearance of threads on one side of the hole is shown. (*Negative No. 98149, Army Institute of Pathology.*)

Fig. 10: A screw properly centered and inserted, after being drilled with a point of optimum diameter (0.110 inch). Note the space between the bone and the root of the thread. (*Negative No. 98153, Army Institute of Pathology.*)

On October 25, 1945, the distal end of the humerus was resected, just proximal to the site of non-union; and an acrylic implant, measuring approximately two inches in length, was fixed to the end of the humerus with two vitallium screws. The proximal three-quarters of an inch of the olecranon process of the ulna was resected, which left a gap of about one-half inch between the distal end of the acrylic prosthesis and the proximal end of the ulna when traction was applied to the forearm in extension (Fig. 3-B). A posterior molded plaster splint was applied to the upper extremity, with the elbow in 150 degrees of extension. This splint was removed in three weeks, and active and passive motion was instituted. There was prompt restoration of painless motion in the elbow joint from 50 degrees of flexion to 135 degrees of extension.

Strength in the arm continued to improve during the next five months, although little, if any, increase in the range of elbow motion occurred. Stability of the joint was good. An evaluation by questionnaire, in October 1946, revealed increased strength and stability without appreciable change in range of motion. Slight discomfort was noted with changes of the weather.

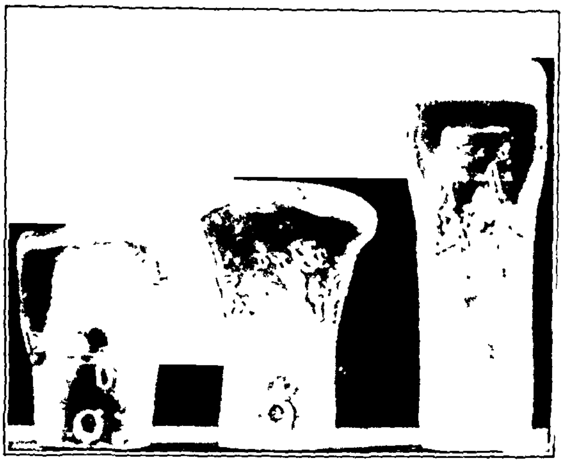

Fig. 4-A

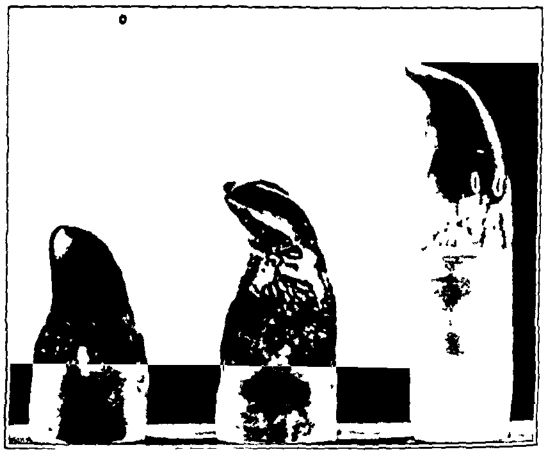

Fig. 4-B

Front view and side view of three varieties of acrylic prosthesis, used to replace the distal end of the humerus. Drill holes have been made in the shafts of the two shorter specimens for the insertion of screws or wire loops. These holes should be drilled at the time of operation, after the prosthesis has been fitted snugly over the end of the humerus.

Case 4. A nineteen-year-old Army sergeant was involved in an automobile accident on June 30, 1945, in Sioux Falls, South Dakota. He sustained a severe crushing injury of his left upper extremity, with compound, comminuted fractures of the distal end of the humerus and the middle thirds of the radius and ulna. On August 11, open reduction was performed on the radius and ulna, and a hanging cast was applied.

On admission to this General Hospital on October 12, the fractures of the radius and ulna were found to be healing satisfactorily with the bones in good alignment. The fracture of the humerus was also healing, but with marked anterior displacement of the distal fragments. No rotation was possible in the forearm, and only a jog of painful motion in the elbow joint. By December 1945, all immobilization had been removed from the arm, and an attempt was made to obtain more motion in the elbow joint with occupational and physical therapy. This was unsuccessful.

Because it was obvious that further motion in the elbow could not be obtained without arthroplasty, on March 14, 1946, the elbow was exposed through a posteromedial incision. The condylar fragments of the humerus were found to be united by a firm fibrous union only. The distal one and one-half inches of the humerus were removed, and an acrylic prosthesis was attached to the distal end of the humeral shaft with one vitallium screw. The proximal half inch of the olecranon was excised. A posterior molded plaster splint was applied, with the elbow in 150 degrees of extension. The postoperative course was uneventful, and motion was started three weeks after the operation. In December 1946, the patient had a range of motion of from 60 degrees of flexion to 150 degrees of extension. Very slight discomfort was experienced as a result of weather changes or heavy lifting.

The prostheses were constructed by members of the Dental Section and the Plastic Eye Laboratory. The material used was veronite, which is a methyl and ethyl methacrylate. This material was cast in the form of models, which were fashioned after the authors' idea of a functional form for the distal portion of the humerus, and did not attempt to duplicate the normal anatomy of the bone (Figs. 4-A and 4-B). The central hole of the prosthesis was drilled out on a lathe. The size of the central cavity was approx-

good threads already cut in the bone and producing a strain which will probably lead to necrosis and early loosening of the screw (Figs. 4, *C*, *D*, *E*, and *F*, and 11). Attention has previously been drawn to the usefulness of a centering device[2] or a drill guide, but it has not been adopted by most operators. A simple device is illustrated (Fig. 3, *A*), which accurately fits the hole in the plate. It is placed in the hole while a few turns are taken with the drill in order to locate the proper center. The drill guide is then removed (Fig. 4, *A* and *B*) and the drilling is continued without it, since otherwise it would tend to become filled with bone chips. In order to have uniform contact between the plate and the screws, it is important to drill vertically to the plate as well as in the center of the hole; the drill guide will aid in determining this direction. Successful immobilization with plates and screws should depend on the strength and rigidity of the plate and on the permanent holding qualities of the screw. Sometimes reference is made to the advantages of inserting screws at odd angles to the plate. Except where the screw may thereby be made to engage the two major fragments of bone, such angles will not contribute to stability, because the purpose of the screw is to fix the plate firmly to the bone. If it is desired to engage both major fragments by placing the screw at an angle, it is probably better to place a separate screw (Fig. 5, *E* and *F*) for this purpose, since angular screws give poor contact with the plate (Fig. 4, *D*). If the screw is angulated in relation to the drill hole, it will not engage the bone on one side of the hole after the first few turns, whereas it will cut too deep and tend to break the bone on the opposite side (Figs. 6, 7, 8, and 9).

Fig. 13

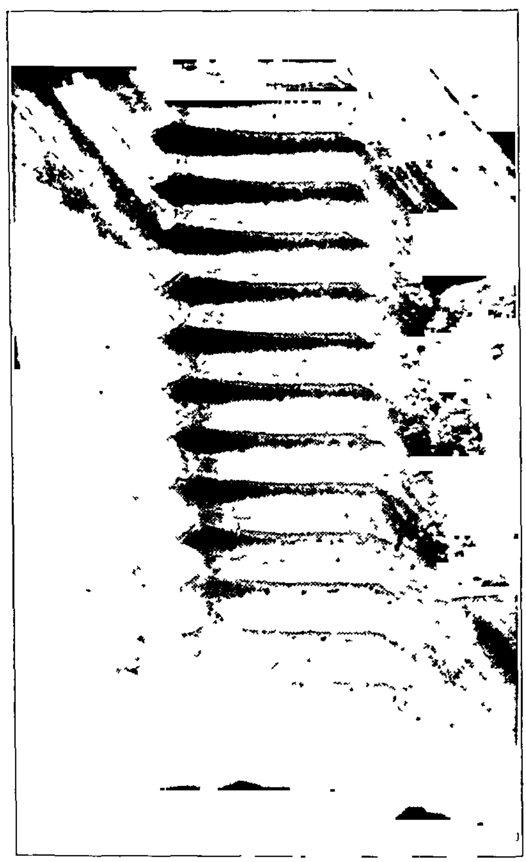

Fig. 14

Fig. 13: The screw was inserted all the way without removal, the cortex measuring fourteen thirty-seconds of an inch (fourteen threads). The screw turned with difficulty after the first six or eight threads, but continued to cut good threads the rest of the way. (*Negative No. 98145, Army Institute of Pathology.*)

Fig. 14: The screw was inserted about half way, removed for the purpose of cleaning the flutes, and then inserted all the way. It turned much more easily in the last half than in the case of Fig. 13, but the quality of the threads appears to be the same. (*Negative No. 98148, Army Institute of Pathology.*)

THE "LATCH" GRAFT

A Combination of Inlay and Intramedullary Graft Which Is Self-Retaining

BY LIEUTENANT COLONEL PETER-CYRUS RIZZO AND CAPTAIN OTTO LEHMANN

Medical Corps, Army of the United States

From Fletcher General Hospital, Cambridge, Ohio

The injuries in World War II have been, to a large extent, injuries to the extremities. Compound fractures due to shell fragments and bullets were frequently accompanied by extensive loss of bone substance. Treatment of simple fractures of the long bones often had to be interrupted because of the necessity of evacuating the patient to another hospital. This resulted in displacement of fragments with subsequent delayed union, malunion, and non-union. Because of these factors, a large number of cases required bone-grafting. In the past few years a good deal has been written about various types of bone grafts, with frequent recommendations of the use of some form of metal device for rigid fixation of the graft and of the fracture fragments. In some instances the results have not been very satisfactory. Frequently drainage from the site of the metal ensued, necessitating subsequent removal of the foreign material. Osteomyelitis, resulting from these infections, was difficult to eradicate.

The types of bone grafts generally used are (1) the onlay graft, (2) the inlay graft, and (3) the intramedullary graft. The onlay graft, although easily applied, requires metallic fixation for good stability. The inlay graft, in order to immobilize properly, has to show a perfect fit. This is often difficult to obtain, particularly in cases with loss of bone substance, and metallic fixation has to be resorted to. Although the intramedullary graft provides excellent fixation of the fragments, technical difficulties are involved in its application; and it has been largely abandoned because of the unsuccessful results, believed to be due to obliteration of the medullary cavity by the graft.

TABLE I

Summary of Forty-six Consecutive Cases in Which the "Latch" Graft Was Used During a One-Year Period

Bones Grafted	No. of Cases	Types of Fracture		Results		
		Simple	Compound	Healed * (Six Months' Observation)	Expected To Heal (Less Than Six Months' Observation)	Failures
Humerus	5	1	4	4	1	0
Radius	9	2	7	8	0	1 (Non-union)
Ulna	4	1	3	3	1	0
Metacarpals	3	0	3	3	0	0
Femur	18	3	15	14	3 (2 Refractures)	1 (Infection)
Tibia	7	2	5	3	2 (1 Refracture)	2 (Infection)
Totals	46	9 (19.6%)	37 (80.4%)	35 (76.1%)	7 (15.2%)	4 (8.7%)

* Bone grafts were considered healed when there was not only roentgenographic evidence of bone bridging, but the patient had been allowed full, unprotected use of the involved extremity during an observation period of at least three months.

two fragments; and, in fact, any pressure exerted as the distal cortex is tapped tends to distract the fragments, depending upon the firmness of the bone clamp.

In fixing a bone graft, a flat-headed screw is often preferred, because it fits the flat surface of the bone; whereas the tapered head tends to split the bone, if forced into the small hole. However, here again the standard screw with the tapered head is equally suitable, if the hole is reamed with a countersink of the exact size and shape as the head (Fig. 3, *E*). This has the added advantage of making the screw less prominent. Where fragments are fixed by screws, without the use of plates, the countersink is also a useful tool, especially since many of these screws are placed at an angle; and with the use of the countersink the head can be recessed and still fit the hole with uniform contact.

It can be seen, therefore, that with two simple accessories—the No. 27 drill and the countersink—one type of screw can serve the purpose of the standard screw, the smooth-shanked screw, and the flat-headed screw, and thereby decrease the stock of screws required. Objection may very well be raised to the addition of another type of screw with the pilot point, which would seem to indicate the necessity of two complete sets. The pilot-point screw is a new feature, which is being submitted for clinical evaluation. It may prove its value by replacing the conventional type in certain lengths, or in all lengths, for those surgeons who prefer it. Either the pilot-point screw or the non-pilot-point type alone suffices for bone surgery, if properly used.

Note: Credit is due Dr. L. B. Tuckerman and his associates, at the National Bureau of Standards, for testing and for technical assistance in this work; and to Mr. J. G. Collison of Greensboro, North Carolina, who developed the screws and centering device, manufactured the plates and drill points to the specifications given, and has offered a number of suggestions in mechanical technique.

Specific comments, criticisms, or recommendations in connection with this subject may be addressed to the Research and Development Board, Office of The Surgeon General, Pentagon, Washington 25, D. C.

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FIG 3-A

E H Four months after simple fracture of left femur Malposition and non-union are shown

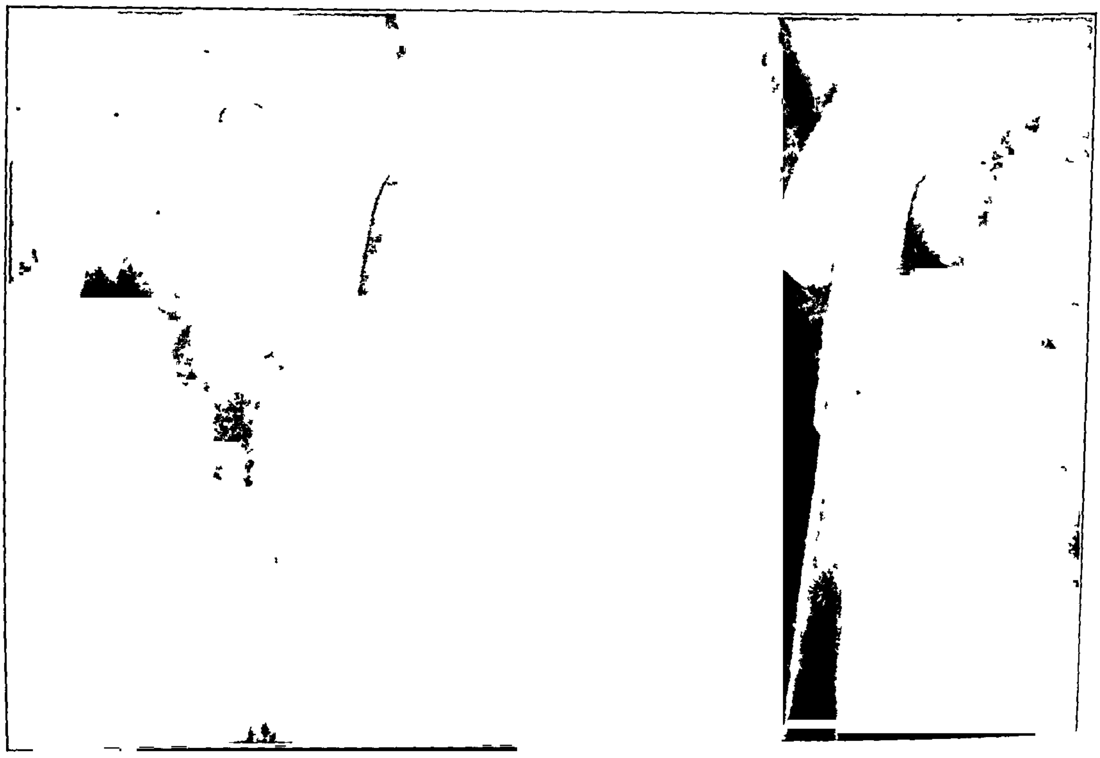

FIG 3-B

Five months after insertion of "latch" graft.

entire graft can now be countersunk into the trough. Once the graft has been fitted into the depth of the trough, it can be driven back or "latched" into the medullary canal of the other fragment (Figs. 1, *C* and 2, *C*). Since the length of the graft exceeds the length of

of the ulna—the result of an initial débridement which was too extensive—it was believed that an acrylic type of prosthesis might be used on the humerus to provide a fulcrum for the elbow joint and still allow early motion in the elbow. This would avoid the long period of time necessary for healing if a bone graft were used to prolong the humerus. It would also avoid the uncertainties of bridging a large gap between the humerus and ulna with a bone graft to accomplish arthrodesis of the elbow. The following case report is illustrative of its use in such a fashion:

CASE 1. On August 18, 1944, an Army sergeant, twenty-three years old, was driving with his left elbow out of a car window, when he was *struck by a truck going in the opposite direction.* He sustained compound fractures of the distal third of the humerus, the olecranon process of the ulna, and the proximal and distal thirds of the radius. He was first given medical treatment in a civilian hospital and then transferred to an Army Station Hospital, where, on August 20, thorough débridement and cleansing of the wound was done and the arm was immobilized in a plaster cast. There was loss of the major portion of the distal third of the humerus, with the exception of part of the medial epicondyle, and loss of the olecranon process of the ulna. The patient was transferred to an Army Air Forces Regional Hospital, where, on August 27, an attempt at secondary closure was made; because of soft-tissue loss, however, it could not be done satisfactorily. At that time the three major nerves in the elbow region, as well as the brachial artery, were intact. The fracture of the distal end of the radius was plated, and the fracture of the proximal end was reduced and held with a wire loop.

The patient was transferred to this General Hospital on September 26, 1944, with a large granulating wound over the posterior aspect of the elbow. On October 12, the loose medial epicondylar fragment was removed, and the wound soon healed. Because of the extensive scarring over the posterior aspect of the elbow, a full-thickness abdominal pedicle graft was applied on March 2, 1945. The patient had a flail elbow, with no active extension and with active flexion of only 20 degrees (Fig. 1-A). Roentgenograms showed the absence of the major portion of the distal five inches of the humerus, and of the olecranon process of the ulna (Fig. 1-C).

On July 12, 1945, the elbow region was exposed through a posterior longitudinal incision; and an

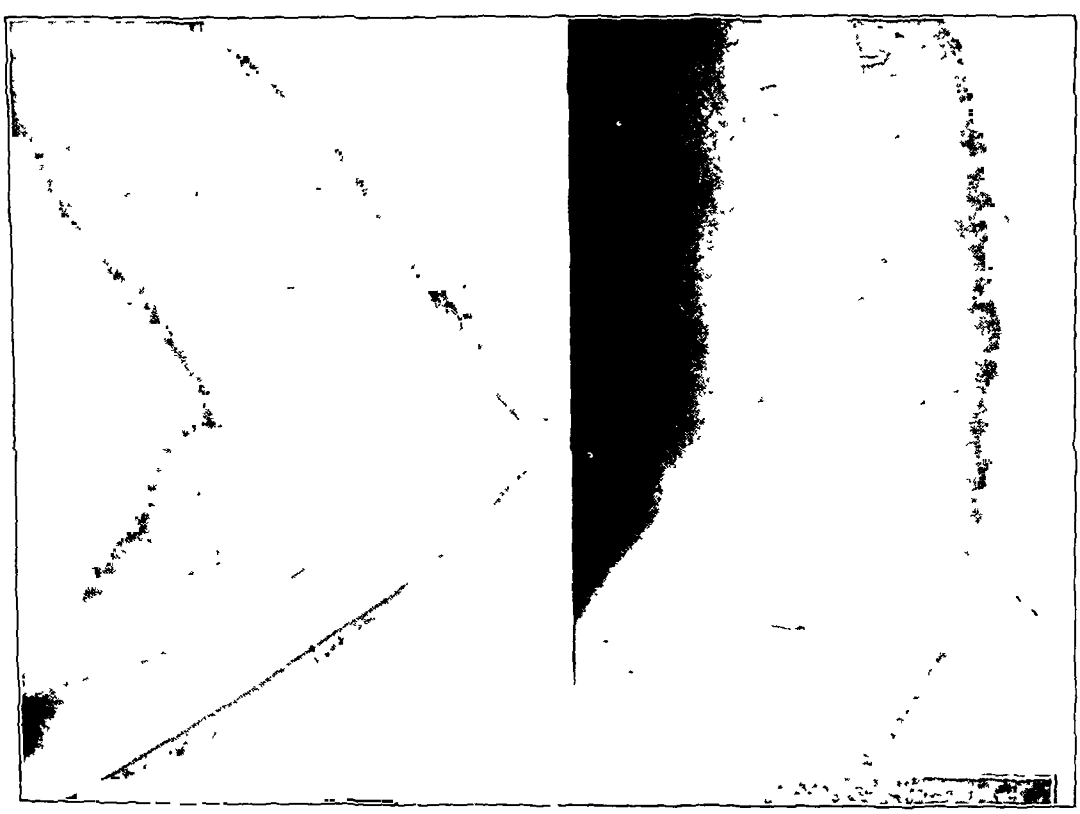

FIG. 1-D

Lateral and anteroposterior roentgenograms of the left elbow, ten weeks after attachment of an acrylic implant to replace the distal third of the humerus. Although the acrylic prosthesis is not radiopaque, the contour of the implant is roughly outlined by calcium deposits in the soft tissues immediately adjacent to it.

fracture site. The wound is closed, and the extremity is immobilized in a plaster cast. If the procedure is carried out correctly, there should be complete stabilization of the fragments and correction of the alignment, even in cases with loss of bone substance.

Plaster immobilization following this procedure has been continued for an average of four months. Roentgenographic studies have indicated an area of rarefaction about the intramedullary portions of the graft at the end of three months. This rarefaction disappears at the end of the fourth month, and after six months the outlines of the graft are almost indistinguishable.

More than forty patients have been successfully operated upon by the technique described. The graft has been used in the femur (Figs. 3-A and 3-B), tibia, humerus, radius, ulna, and metacarpals (Figs. 4-A and 4-B).

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DISCUSSION

(*Continued from page 327*)

If the blood supply to the head is inadequate at the time of the bone-grafting, then revascularization of both the head and the graft are necessary to obtain a good end result.

DR. MARY SHERMAN, CHICAGO, ILLINOIS: I wish to make only one point. In our opinion there is no such thing as delayed aseptic necrosis. If one studies a series of femoral-neck fractures, it becomes apparent that there is a sudden interruption of the blood supply due to the break or to the degree of surgical intervention, and either the head dies at once, *in toto*, or it never dies at all. The reason that roentgenographic and clinical changes do not show up until later is also evident from pathological studies. The dead portion of the bone is quite inert, does not collapse, and does not show any sign of change until revascularization has begun. When absorption has become apparent on the roentgenogram, the dead bone has been weakened by advancing replacement, and it is at that time, if weight-bearing is permitted, that fracture and separation may occur. Replacement, since it always begins at the fracture edges, is first evident in the superior and inferior margins of the head. The triangular area of density, which stands out so clearly, represents the unreplaced portion which has not yet been invaded, may never be invaded, or may even be cast off as a sequestrum.

DR. PHILIP D. WILSON, NEW YORK, N. Y.: In answer to a point that Dr. Colonna made, I think this operation, of course, is a modification of his procedure. There is no question about that. I think the point is that, according to his original description, there is a direct thrust, the angle of the neck is eliminated, and the quality of the bone is similar to that of the knee. I think the question is whether this operation is the Colonna type or the Whitman type. I can assure you the neck was entirely removed, and the remodeling has been directly under the trochanter.

There is one final point which I should like to make, that is, the consideration of the age of the patient in determining what procedure should be followed. I am very sure that I would not want to do this operation on a patient over sixty. It is a very complicated procedure. There is a lot of surgery; and there is the problem of patients who, as a rule, are not very good at exercise, and in whom joint immobility is rapidly developing. I think, therefore, that beyond that age we should choose a simpler type of procedure.

either alone or in combination with a conventional arthroplasty or resection. It appeared likely that the entire ununited distal fragment of the humerus might well be replaced with a functional type of plastic prosthesis. This would restore the fundamental principles of the hinged type of joint normally present in the elbow, inasmuch as the proximal portion of the ulna was undamaged and could furnish a satisfactory point of rotation. The use of a plastic prosthesis in this type of injury is illustrated by the following three cases:

CASE 2. An Army private, twenty-eight years old, was injured by enemy shell fire in Normandy, on June 6, 1944. He sustained compound fractures of the distal third of the right humerus and of the proximal third of the left femur. Upon admission to this General Hospital on October 13, 1944, both clinical and roentgenographic evidence of non-union of the femur was present; and a bone graft was subsequently applied to this bone to obtain union. Non-union of the fracture through the distal third of the humerus was also present, with a few degrees of motion both at the fracture site and in the elbow joint (Fig. 2-A). There was a considerable loss of soft tissue over the posterior aspect of the elbow, and an incomplete paralysis of the ulnar nerve.

An abdominal pedicle flap was applied to the posterior aspect of the elbow on March 19, 1945. On May 26, arthroplasty of the elbow was performed. The distal one and one-half inches of the humerus, which included the site of non-union, was resected; and an acrylic implant was inserted. The proximal three-quarters of an inch of the olecranon process of the ulna was also removed. The acrylic implant was fitted snugly over the end of the humerus and fixed with tantalum wire (Fig. 2-B). A posterior molded plaster splint was applied, with the elbow in 150 degrees of extension. This splint was removed in three weeks, and active motion was instituted in the elbow joint. Restoration of motion in the elbow joint, from 50 degrees of flexion to 140 degrees of extension, without pain, was promptly attained.

The patient was discharged from the Army on a certificate of disability on December 11, 1945. At that time the range of motion in his elbow joint had not changed; but the strength in his arm was much improved, and there was excellent stability in the joint (Figs. 2-C and 2-D). A personal communication, in October 1946, indicated that there was no change in range of motion and no pain, but that an increased sense of stability and strength was present.

CASE 3. A twenty-year-old Army private was wounded in combat in Belgium on January 3, 1945, sustaining a compound, comminuted fracture through the distal third of the right humerus. On admission to this General Hospital on June 19, there was definite non-union of the humeral fracture, with complete destruction of the normal anatomical contour of the supracondylar region (Fig. 3-A). The humerus was very flail at the site of the pseudarthrosis, and there was little active power in flexion of the forearm.

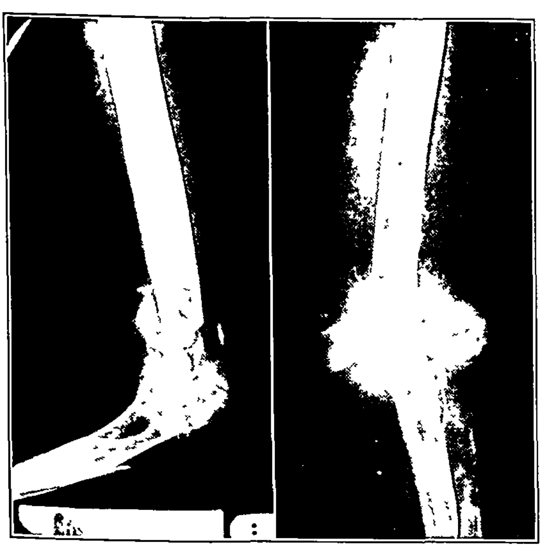

FIG. 3-A

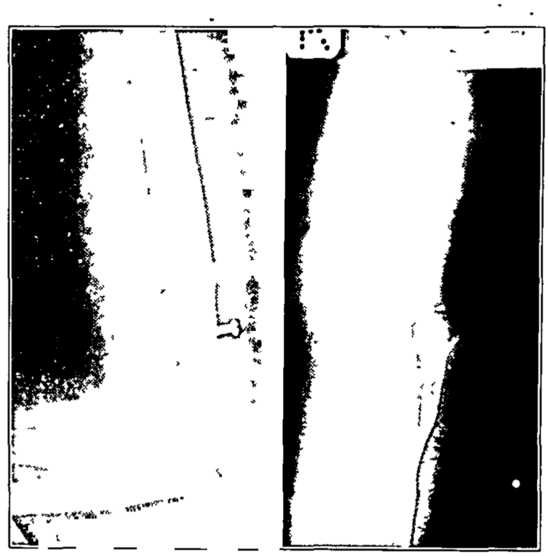

FIG. 3-B

Fig. 3-A: Case 3. Lateral and anteroposterior roentgenograms of the right elbow, six and one-half months after a compound fracture involving the distal end of the humerus. There was a flail pseudarthrosis of the humeral fracture, with very little active flexion of the forearm.

Fig. 3-B: Lateral and anteroposterior roentgenograms of the right elbow, three months after attachment of an acrylic prosthesis to the humerus with two vitallium screws. The tip of the olecranon has been resected. Some deposition of calcium is present in the soft tissues adjacent to the proximal end of the acrylic implant. A small fragment of bone, presumably from the lateral humeral epicondyle, is still present. Good stability of the elbow joint is present, as well as motion of 50 degrees of flexion to 135 degrees of extension without pain.

removed; a bone graft filled the space in one and no graft was used in the other. No difference was reported in the end result. Crossan stated: "All cases of compression fracture of the scaphoid demand open reduction". In discussing fractures of the tarsal navicular, Morrison said: "The scaphoid fragments must be moulded into place. Uncommonly open operation is necessary to obtain a good result."

In many cases treated by manipulation, a good functional result is reported after four or six months, and the case is closed. It is believed that, in many patients with so-called good results, pain and disability appear later as the traumatic arthritis develops, and operative procedures are required a year or more later.

Dick has reported a case of fracture-dislocation of the tarsal navicular in which two attempts at manipulative reduction failed, as did also a third attempt at manipulation aided by skeletal traction. At open operation, reduction was effected easily. The foot was immobilized in plaster for ten weeks, and four weeks later the patient returned to duty with somewhat limited mid-tarsal motion but without pain. After two months this patient returned, complaining of pain. Roentgenograms at that time demonstrated arthritic changes. Fusion of the talonavicular and cuneonavicular joints was then performed. Dick states: ". . . if open reduction is required for a fracture-dislocation of the tarsal navicular, primary fusion of the involved joints is indicated. Even in closed fractures of the tarsal scaphoid in which manipulative reduction succeeds, consideration should be given to the desirability of primary fusion of the involved joints when there is distortion of the joint surfaces."

Seven cases of injuries to the tarsal navicular have been treated by the author, and two procedures have been used. These cases have been grouped to help formulate a program for the treatment of the injuries.

Fig. 1-A

Case 2. Demonstrates fracture and dorsal dislocation of the navicular after attempted closed reduction.

imated for each case by a preoperative measurement of the roentgenograms of the distal shaft of the humerus, over which the prosthesis was to fit. At the elbow a standard operative approach was used, usually modified by the type of injury and the presence of previous scars or skin grafts. The prosthesis was secured to the distal portion of the humerus either by tantalum wire or vitallium screws; these were placed through holes in the prosthesis, which were easily drilled at the time of operation, after the prosthesis had been fitted snugly over the end of the humeral shaft.

DISCUSSION

Three of the patients described have been followed for periods ranging from nine to eighteen months since the operation. Several striking things have been noted. Immediately after subsidence of the postoperative reaction, motion was restored to the maximum amount obtained; and, as weeks went by, strength in the flexor and extensor muscles improved, but very little further improvement in range of motion occurred. This was probably due to the fact that, from the start, very little pain was present on motion; and at the last evaluation the patients complained of no pain whatever. Furthermore, the elbows were comparatively stable.

Inasmuch as the distal end of the humerus is enclosed in this more or less impervious acrylic cap, the fate of this portion of the bone in regard to nutrition and future atrophy is uncertain. This will have to be determined by a longer period of observation. The purpose of this report is not to present end-result studies, but rather to stimulate interest in a simple type of procedure, which apparently restores motion to the elbow quickly and relatively painlessly. The authors believe that this procedure might possibly be of benefit in ankylosed elbows resulting from rheumatoid arthritis.

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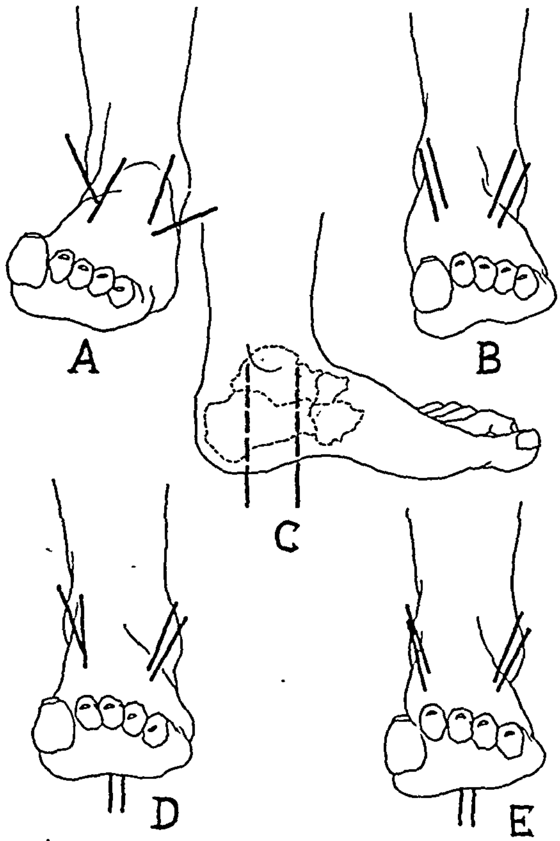

FIG. 2
Showing interrelation of motions in tarsal joints.

question arises as to whether triple arthrodesis plus arthrodesis of the cuneonavicular joints should be performed, rather than localized arthrodesis of the talonavicular and cuneonavicular joints.

The author believes that a more extensive arthrodesis should be performed, since the localized arthrodesis eliminated nearly all of the inversion and eversion of the foot in the cases just presented. Experimental procedures were carried out to demonstrate the interrelation of motions in the tarsal joints. A leg which had been amputated because of diabetic infection, with no structural abnormalities, was used (Fig. 2, *A*). A Kirschner wire was drilled into the talus and one into the navicular, close to the joint line on the medial aspect of the foot. Likewise, wires were placed in the calcaneus and in the cuboid, on the lateral margin of the foot. When the foot was passively twisted into inversion, it showed a wide angle between the Kirschner wires, demonstrating the extensive motion in these two joints. The foot was then twisted into eversion, and showed little or no angle between the wires (Fig. 2, *B*). Thus a rather wide total angle of motion is demonstrated in the normal foot. Two Kirschner wires were then drilled through the plantar aspect of the foot, through the calcaneus and into the talus (Fig. 2, *C*), thus producing a pseudo-arthrodesis of the subtalar joint. Figure 2, *D* demonstrates the small amount of motion present on inversion of the foot after fixation of the posterior joint, and Figure 2, *E* demonstrates the position of the wires on eversion. The fixation of the posterior joint eliminates nearly all of the motion of the anterior joints. Fixation of the talonavicular joint (not illustrated) produces a marked diminution in motion of the other two joints, although not quite so great as in the case illustrated. From these findings, it was felt that the type of arthrodesis in fractures of the tarsal navicular should be the triple arthrodesis with arthrodesis of the cuneonavicular joint.

It is the opinion of some that, after arthrodesis of the talonavicular and cuneonavicular joints, a compensatory abnormal degree of motion will eventually be produced in the calcaneocuboid and talocalcaneal joints. It is felt, however, that an abnormal range of motion of these joints would be another factor in producing pain. The remaining cases demonstrate the more extensive type of arthrodesis.

CASE 3. A corporal was injured October 1, 1943, when he caught his foot between the bed rail and the bed springs of an upper bunk, producing acute plantar flexion, as he fell to the floor of his barracks. He sustained a fracture-dislocation of the right tarsal navicular (Fig. 3-A). On October 8, under anaesthesia, a manipulation was performed; reduction could be obtained, but could not be maintained. Moderate dislocation recurred, but, since there was fairly good bone contact, conservative treatment was followed; and after six weeks the soldier was placed in a walking cast. Because of pain in the foot he was unable to get along, and on January 12, 1944, a triple arthrodesis plus fusion of the cuneonavicular joint was performed. Seven months after the injury he had mild pain in his foot; this gradually diminished, and at the time of discharge from the convalescent ward he complained of little or no pain except after very long walks. He had good ankle motion and the hind part of the foot was solid (Fig. 3-B).

CASE 4. While this corporal was cleaning his gun on the Anzio Beachhead, Italy, February 22, 1944, his position was shelled and his gun discharged accidentally, injuring his left foot. After initial treatment

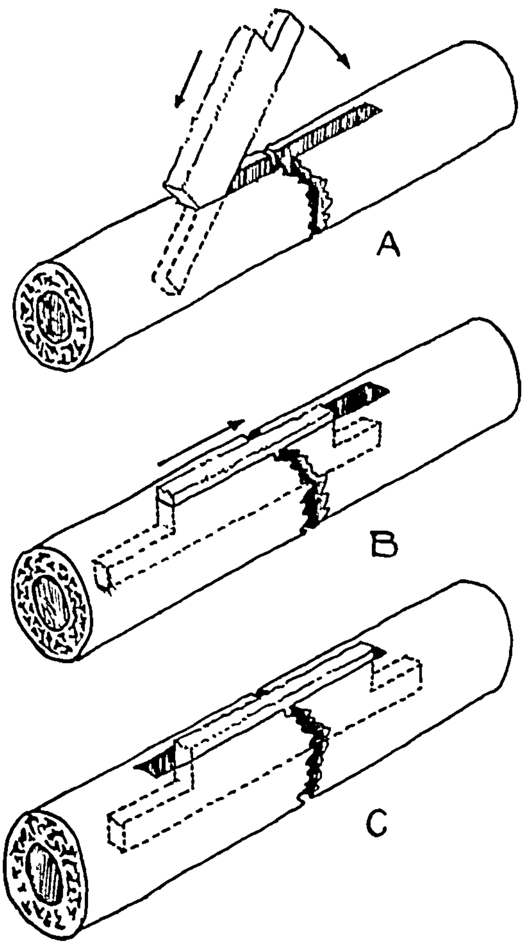

FIG. 1

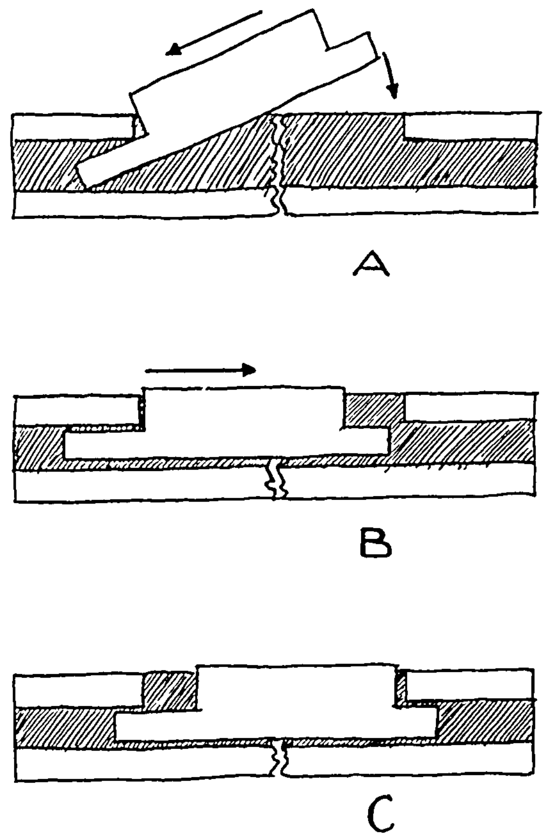

FIG. 2
Diagrams of operative technique.

Self-retaining grafts, which give proper immobilization of the fracture fragments and fixation of the graft without the use of metallic fixation, have been used by Kirk, Albee, Brittain, Ryerson, and others. The graft to be described here has proved efficient in fulfilling the requirements of rigid fixation of both the fracture fragments and the graft without metallic fixation. It is a combination of inlay and intramedullary graft.

OPERATIVE PROCEDURE

The fracture fragments are widely exposed. Realignment of the fragments is carried out, if necessary. By means of the twin saw, a narrow trough is made in both fragments, crossing the fracture line or the bone defect. The width of the trough should be slightly less than the thickness of the tibial graft to be used; the length varies with the bone to be grafted. The medullary canals of both fragments are opened.

A bone graft is cut from the tibia, and should be at least three or four centimeters longer than the trough. The graft should be the width of the bone to be grafted, minus the thickness of one cortex. If a bone defect is to be bridged, the graft should be cut so as to contain part of the medial or lateral cortex of the tibia. If non-union is present but no defect, the graft should be taken from the middle of the anteromedial tibial surface, so as to be of even thickness. The graft is then shaped by means of a saw or rongeur so as to have two narrowed-down prolongations, one longer than the other. These prolongations should be somewhat narrower than the width of the medullary canal. The distance from the end of the shorter prolongation to the base of the longer prolongation should be equal to the length of the trough.

The graft is then placed *sideways* into the trough. The longer prolongation is inserted up to its base into the medullary canal of one of the fragments (Figs. 1, *A* and 2, *A*). The

The following case is presented, not as an injury, but as a case of tuberculosis of the tarsal navicular, and represents the same problem of arthrodesis as in the patients with injuries.

CASE 5. This officer, a major, sprained his left ankle in April 1942, and continued to have pain and swelling after that time. Roentgenograms showed a destructive process in the navicular. He was transferred to Fitzsimons General Hospital on November 2, 1944. Mantoux tests were positive, but there was no active pulmonary disease. The patient was kept at rest. On January 23, 1945, the navicular was excised and a Dunn arthrodesis was performed by displacing the foot backwards. The pathologist reported typical tuberculosis of the navicular. At the time of discharge, six months after operation, the patient was walking with a normal gait, with good ankle motion, and without pain.

CASE 6. On April 2, 1944, this nurse, a second lieutenant, was thrown from a horse and fractured her tarsal navicular on the right. The foot was placed in a cast for six weeks, then she gradually became ambulatory and, after four weeks more, returned to duty. At first she had only mild aching pain; but began to have more severe pain, which was progressive. She was admitted to this Hospital on January 5, 1945. On March 5 a triple arthrodesis, plus arthrodesis of the cuneonavicular joints, was performed. Two months later full weight-bearing was possible in a cast, and there was good bony union. All immobilization was discarded, and three months after the operation she was bearing full weight without a limp, without pain, and with good ankle motion (Figs. 4-A, 4-B, and 4-C).

CASE 7. On January 14, 1945, this soldier, a private, sustained a compound fracture of the tarsal navicular when his rifle accidentally discharged. The wound of entrance was on the dorsomedial aspect of the foot, and the wound of exit on the plantar surface. After débridement, a plaster cast was applied and maintained until arrival at this Hospital, April 23, 1945. Immobilization was discontinued gradually, and a program of progressive activity was started. Pain persisted in the mid-tarsal area and gradually became worse, associated with a marked limp. On September 15, 1945, a triple arthrodesis, plus fusion of the cuneonavicular joint, was performed. In January 1946 the patient was bearing full weight without support, and at the time of discharge, in March 1946, he had no pain and walked without a limp.

From the cases just described, it is apparent that traumatic arthritis is a very common sequel to fracture-dislocation of the tarsal navicular. In the author's opinion, the results obtained in cases of triple arthrodesis plus arthrodesis of the cuneonavicular joints are superior to the results obtained after fusion of only the involved joints. On the basis of

FIG. 4-A

Case 6. Dislocation and fracture of the navicular.

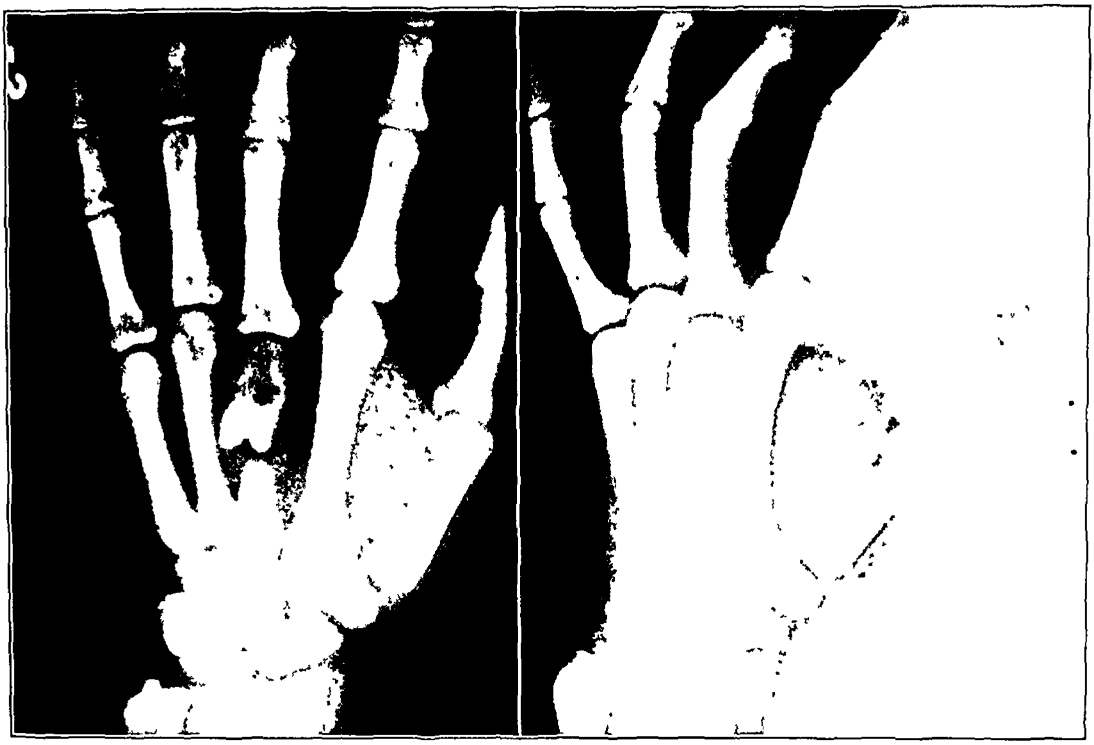

FIG. 4-A

N. P. Four months after compound fracture of left third metacarpal. Loss of bone substance is evident.

FIG. 4-B

Three months after "latch" graft has been inserted.

the trough, both prolongations will be well engaged in the medullary canals of the fragments; they act as intramedullary grafts, but do not fill the entire medullary cavity. Inasmuch as the graft is cut slightly thicker than the width of the trough, a tight fit is obtained, as in a well-applied inlay graft. Bone chips or slivers are packed around the

such a small series of cases, however, it is not logical to advise the more extensive arthrodesis in every case of fracture or dislocation; there will certainly be cases in which this is not necessary. For example, in the case of an acute injury where open reduction is indicated, the circulation of the foot and the general tissue reaction may contra-indicate an extensive surgical procedure. In such cases it is conceivable that the localized arthrodesis would be the procedure of choice. The author does feel, however, that in the absence of such circumstances the triple arthrodesis, plus arthrodesis of the cuneonavicular joints, offers the best assurance of eliminating pain in the foot, and that it should be carried out in all cases of traumatic arthritis about the navicular.

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THE TREATMENT OF INJURIES TO THE TARSAL NAVICULAR

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Injuries of the tarsal navicular are relatively uncommon, but are important because of the marked disability which usually results. Wilson has stated that fractures of the tarsal navicular represented 0.26 per cent. of all injuries in the large group of fractures reported by him. The literature is singularly devoid of information concerning fractures of the navicular, and many times the subject is dismissed with the statement that manipulation and immobilization by cast provide the only treatment. Traumatic arthritis in this portion of the foot, however, often becomes very crippling, and the frequency with which the arthritis occurs after injuries to the navicular seems to indicate that the initial treatment is often inadequate.

Injury to the tarsal navicular may occur in various ways. It may be caused by a fall onto the foot from a height, with a resulting crushing injury to the bone. The presence of plantar flexion at the time of impact, or acute plantar flexion alone, may cause a rupture of the dorsal ligaments and fracture of the inferior portion of the navicular, along with dorsal dislocation. Acute inversion and adduction of the foot may produce fracture-dislocations in the same manner.

Berman, in 1924, reported a case of dislocation of the navicular which was treated by manipulation; after one year this patient still had pain whenever he was on his feet for too long a time. In a review of the literature, Berman reported twenty-seven cases, which were treated as follows: In eight cases reduction was achieved by manipulation; in four cases open reduction was done; four cases were treated by excision of the navicular; in eight cases no reduction was done; two cases were treated by amputation of the foot; and in one case no record could be found.

The wide variation of treatment indicates uncertainty concerning a satisfactory method. This study was, therefore, made in an effort to outline a satisfactory plan of treatment.

The most conservative method of treatment—that is, manipulation to reduce the fracture and dislocation—should certainly be attempted as an initial procedure. Henderson points out that considerable force may be necessary to restore the fragments to their normal positions. Cases have been reported by Penhallow and by Lehman and Eskeles, in which manipulation produced a good reduction and, after immobilization in plaster casts, good functional results were obtained. However, when some deformity of the navicular remains after manipulation, it is likely that traumatic arthritis will occur and will require an arthrodesing procedure. Since the talonavicular joint is continuous with the subtalar joint, the motions of inversion and eversion of the foot are disturbed by abnormalities of the surface of the talonavicular joint. Severe pain on weight-bearing and prolonged, permanent disability will result. In addition, bony prominences, secondary to persistent displacement of the fractured fragments of the navicular, tend to become painful.

Wilson has recommended that, when the patient is seen early, a closed reduction be attempted with fixation for six to eight weeks. He further recommended that, when complete reduction cannot be accomplished or when the patient has been seen after eight or ten days, arthrodesis of the talonavicular joint be advised. He felt that motion at the cuneonavicular articulation is so slight that arthrodesis of that area does not seem necessary. Six patients treated by fusion in this area were reported; five had good results and one had a fair result.

Crossan reported two cases of untreated fractures, in both of which the navicular was

had a breech delivery, with trauma to the left arm The mother stated that the arm had been dislocated during delivery, and had been strapped to the infant's side for one week.

Physical examination showed atrophy and marked shortening of the left brachium, as compared with that on the opposite side Abduction was possible to 45 degrees The shoulder easily became dislocated posteriorly. Roentgenograms showed marked varus of the humeral neck, with closure of the medial portion of the epiphyseal plate (Fig 4-A) Motion was markedly restricted in all directions (Fig 4-B).

On December 5, 1934, a wedge osteotomy of the neck of the left humerus was done. The arm was abducted while the head was maintained in position, thus correcting the varus deformity. A plaster shoulder spica was applied with the arm in 90 degrees of abduction Six weeks after operation the cast was bivalved, and active and passive exercises were begun One week later the cast was removed, and a

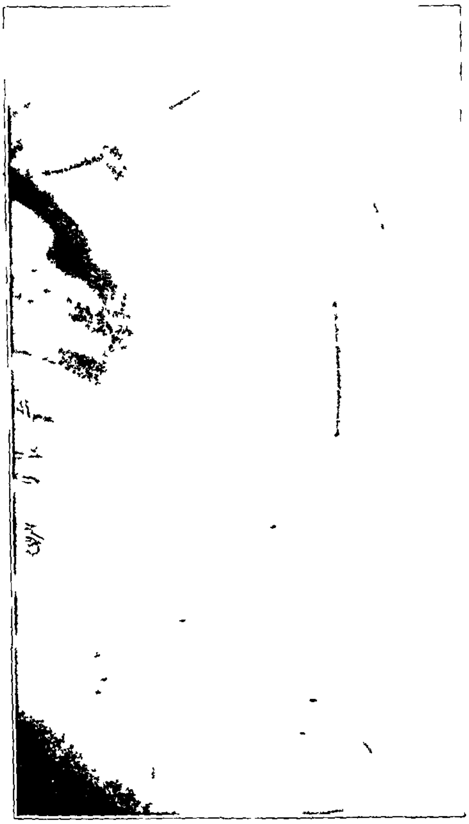

FIG 4-A
L M Before correction.

FIG 4-C
Thirteen months after operation.

FIG 4-B
Before correction.

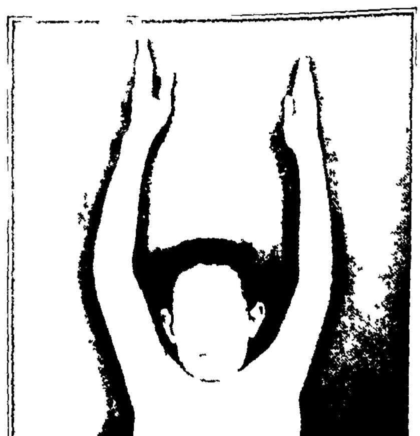

FIG. 4-D
Thirteen months after operation

CASE 1.* On June 28, 1942, this patient, aged twenty-seven, accidentally fell a distance of about twenty feet, landing on both feet. He sustained fractures of the tarsus on the right and fractures of the metatarsals on the left. Roentgenograms of the right foot showed dislocation of the navicular, fracture-dislocation of the cuboid-metatarsal joints, and fractures of the necks and heads of the second, third, fourth, and fifth metatarsals. Skeletal toe traction was applied and a manipulation was performed. The dislocation of the navicular was reduced easily, but likewise became redislocated easily. On July 11, open reduction was performed; arthrodesis of the talonavicular and cuneonavicular joints was carried out, a small vitallium nail, driven through the navicular into the talus, being used to maintain position. Other procedures were employed on the other injuries. Weight-bearing was started after eight weeks, and immobilization discarded three weeks later. This patient continued to have some mild pain after five months, but it was difficult to ascertain the origin of the pain because of his multiple injuries. A late follow-up was not obtained. There was marked limitation of inversion and eversion of the foot.

This case demonstrates the difficulty in obtaining and maintaining reduction of a dislocated navicular.

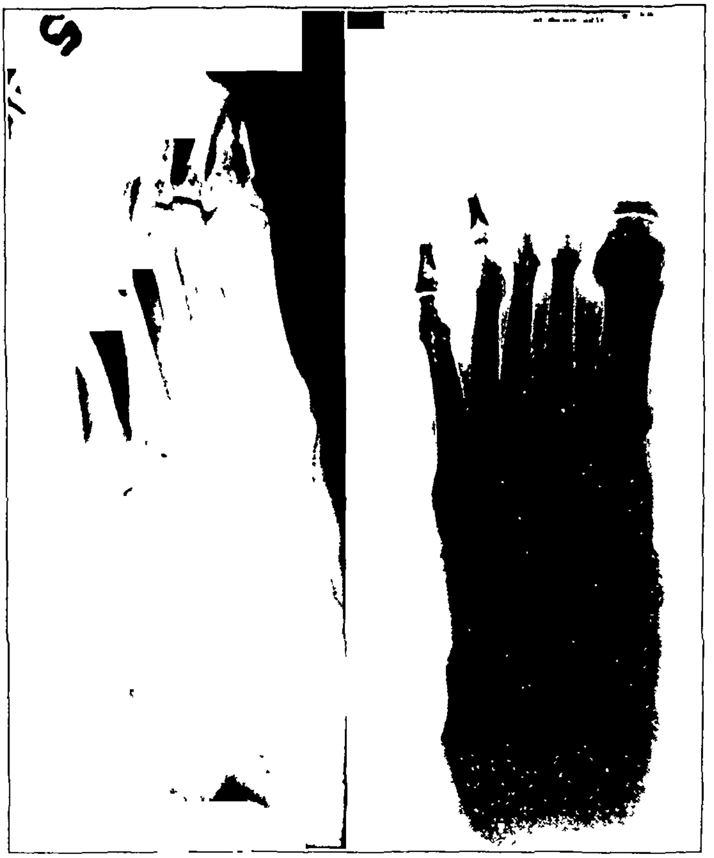

FIG. 1-B

Demonstrating solid bony fusion, ten months after arthrodesis of the talonavicular and cuneonavicular joints. An inlay tibial bone graft was used.

CASE 2. On February 15, 1944, this private first class accidentally fell from the wing of a grounded airplane and landed on his left foot, sustaining a simple fracture-dislocation of the navicular. On the following day a closed reduction was attempted, but was unsatisfactory (Fig. 1-A). On February 28, an open reduction was performed and an arthrodesis of the talonavicular and cuneonavicular joints was carried out; an inlay tibial bone graft across these joints was used. Six weeks later gradual weight-bearing in a cast was started. The cast was discarded after four months and the soldier gradually became ambulatory without support. At the time of discharge from the Hospital, December 16, 1944, the patient was walking, and complained of a very mild pain in the left foot (Fig. 1-B). He had complete ankylosis in the area of the operation, without appreciable inversion or eversion of the foot. Good ankle motion was present.

These two cases represent the difficulty in maintaining reduction after manipulation, and demonstrate arthrodesis of the localized area,—that is, the talonavicular and cuneonavicular joints. In both cases, little or no inversion or eversion remained. It is believed that some of the pain was derived from arthrodesis of only two joints instead of arthrodesis of *all* the inverting and everting joints. Furthermore, it is felt that an undue strain is thus placed upon the fused area.

There has been much discussion in the literature regarding the interrelationship of motion between the talonavicular, talocalcaneal, and calcaneocuboid joints. Some authors have advised subtalar arthrodesis for fractures in this area, such as fracture of the calcaneus, while others state that if subtalar arthrodesis is indicated, a triple arthrodesis should be performed because of the interrelationship of motion. In the problem being discussed, the

* This patient was treated by the author at the University Hospital, Ann Arbor, Michigan.

AUTONOMIC CONTROL OF SYNOVIAL-FLUID REACTION *

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In an earlier investigation, determinations were made of the pH changes in the synovial fluid of dogs in relation to blood pH and to various other physiological and chemical conditions.[2] Certain mechanisms involved in the exchange of fluid and electrolytes between blood, tissues, and joint cavity were inferred from the nature of these relations. In order to elucidate the effects of autonomic vasomotor controls on the electrolyte exchanges, the method of perivascular sympathectomy of the femoral vessels has been applied. Comparison of responses of the normal joint with those of the joint on the denervated side in the same animal has permitted a tentative evaluation of various factors involved in fluid and electrolyte exchange. It is the purpose of this paper to determine the nature of the autonomic regulation of normal balance in these tissues. As an index of changes within the joint, the pH of the synovial fluid was followed over a period of time, as in the earlier study.

METHOD

The determinations of pH in blood and synovial fluid were made as in the earlier investigation, except for one modification. The method was to insert a needle reference electrode into the synovial fluid. A capillary glass electrode, mounted in the needle, also made contact with the fluid. The needle was electrically insulated on the outside by application of a lacquer which was resistant to heat and moisture. It was silver plated inside by electrolysis of dilute potassium silver cyanide. Silver chloride was deposited by electrolysis of dilute hydrochloric acid. The glass electrode was prepared as a very fine capillary, and filled with tenth-normal hydrochloric acid. The end of the capillary was carefully sealed in the flame of a micro burner. A silver-silver chloride electrode, prepared from 18-gauge silver wire, made contact with the acid. The pH was determined by means of a vacuum-tube electrometer. The results were calculated, as in the earlier work, by calibration against standard solutions. The two electrodes were assembled as shown in Figure 1.

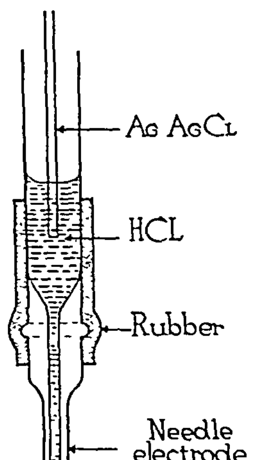

FIG. 1

Glass-electrode assembly for *in vivo* pH determinations.

In the present work, the capillary glass electrode was mounted in the needle electrode by means of a short piece of thick-walled rubber tubing, attached to the upper end of the needle. The tubing replaced the syringe barrel, used for that purpose in the previous work. The needle was inserted into the knee-joint cavity in such a manner that it stood in a nearly vertical position when the glass electrode was mounted. It was unnecessary to remove the electrode at any time during the course of an experiment. The rubber tubing is a connection of sufficient elasticity to allow for unexpected movements of the knee joint, without danger of breaking the glass electrode. Electrodes used in the determination of blood pH were mounted in a similar manner, but the needle electrode was permitted to lie flat in a horizontal plane, resting on a pad of cotton. The pH determinations were carried out as described previously. Electrodes were calibrated on standard solutions at 37 degrees centigrade.

* This investigation was supported, in part, by a grant from Nutrition Research Laboratories.

overseas, he arrived at Fitzsimons General Hospital on July 16, 1944. There was moderate stiffness of the tarsal joints, but all wounds had healed. Roentgenograms showed a comminuted fracture of the navicular with fracture of the base of the first cuneiform. It gradually became evident, because of the traumatic arthritis and malunion, that arthrodesis was necessary. On October 20 a triple arthrodesis was performed with excision of the remaining fragments of the navicular and displacement of the talus forward to articulate with the cuneiform bones. By January 23, 1945, the arthrodesis was solid clinically, and roentgenograms showed early bony union. The patient had some limitation of motion of the ankle joint, but by April 1945 he walked without limp or pain. A good result was obtained.

Fig. 3-A
Case 3. Comminuted fracture of the navicular with dorsal subluxation.

Fig. 3-B
Seven months after injury and three months after arthrodesis.

TABLE II

COMPARISON OF NORMAL AND DENERVATED SIDES FOLLOWING STIMULATION

Dog No.	Joints *	Resting pH	pH Determinations at the Following Intervals After Stimulation:				
			1 Min.	5 Min.	10 Min.	20 Min.	30 Min.
6	N	7.43	7.28	7.28	7.42		7.44
	S	7.46	6.92	6.86	7.11	7.10	
7	N	7.28	7.12	7.07	7.20	7.25	7.25
	S	7.20	6.87	6.65	6.75	6.80	
8	N	7.24	6.94	6.98	7.18	7.25	
	S	7.28	6.65	6.63	6.70	6.70	
9	N	7.33	7.10	7.17	7.25	7.30	7.35
	S	7.36	7.13	7.13	7.22	7.22	7.33
10	N	7.46	6.91	6.99	7.16	7.22	7.23
	S	7.24	6.89	6.78	6.62	6.58	6.60
13	N	7.28	7.13	7.19	7.24	7.32	7.32
	S	7.36	7.17	7.17	7.15	7.16	
14	N	7.45	7.32	7.38	7.40	7.40	
	S	7.37	7.15	7.13	7.10	7.10	
15	N	7.29	7.05	7.14	7.19	7.29	7.32
	S	7.24	7.00	6.97	6.94	6.98	7.00
16	N	7.41	7.22	7.29	7.40	7.43	
	S	7.31	7.09	7.14	7.10	7.13	7.16
18	N	7.33	7.10	7.15	7.18	7.26	7.24
	S	7.24	7.02	7.00	7.07	7.12	7.13

* *N* denotes normal side, *S* sympathectomized side.

fluid pH. At the time of the final experiment, constriction of the femoral blood vessels and mild oedema distal to the surgical site were clearly evident.

The operation was performed in the following manner: An incision was made parallel to the femoral vessels, and the adipose tissue was separated from the vessel sheath. By sharp dissection, the sheath was carefully removed from the femoral vessels, and the overlying structures were closed with interrupted sutures.

One week after the performance of the perivascular sympathectomy, the electrometric pH determinations within the joints and veins were made. The femoral nerves, arteries, and veins were exposed on both sides. Both femoral nerves were cut and tied, preparatory to stimulation. Four sets of electrodes were inserted, one into each knee-joint cavity under the patella, and one into each femoral vein. The electromotive force of each was determined for a period of ten to fifteen minutes, until the values of all became constant to two or three millivolts (0.03 to 0.05 pH).

Each experiment had as its objective the comparison of the effects of nerve stimulation and muscle contraction on the joint pH of the two sides. The blood pH was also followed on both sides. After peripheral faradic stimulation of each nerve for one minute, the corresponding pH values of joint and blood were read at short intervals for a period of thirty minutes or more. The two joints were compared with respect to the initial pH change after stimulation, and with respect to variations of pH over the entire period. In five experiments, acute perivascular sympathectomy was performed on the normal side after its responses had been studied with the sympathetics intact. Immediately after sympathectomy, the response to nerve stimulation and muscle contraction was studied for comparison with data obtained as described. The complete record of such an experiment is given in Table I.

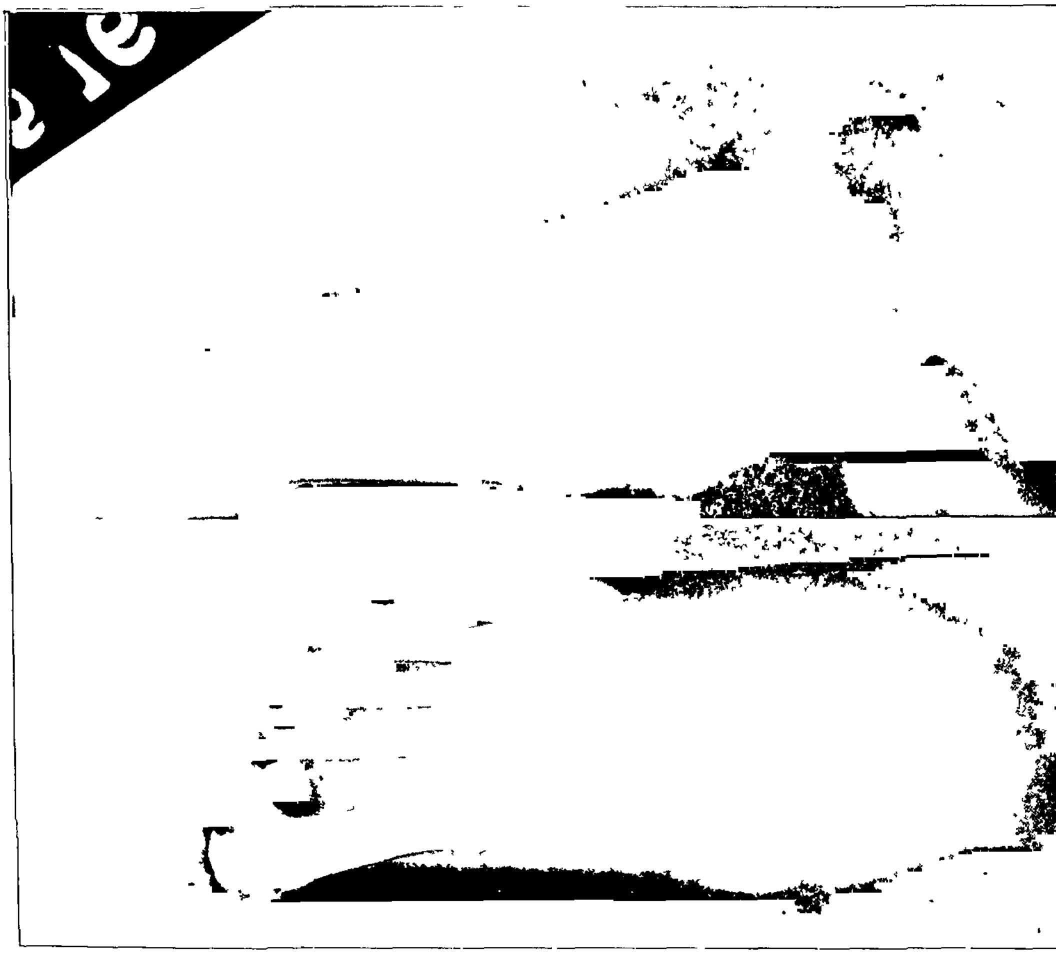

Fig. 4-C

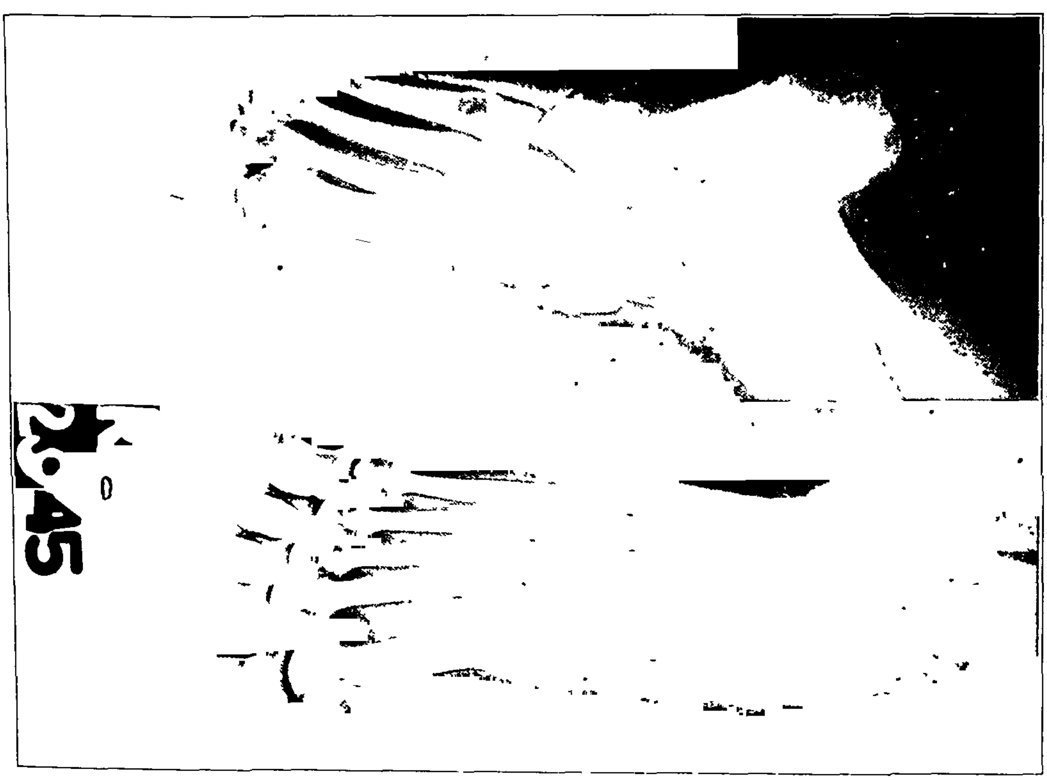

Fig. 4-B

Fig. 4-B: Roentgenograms ten months after injury, showing diminution of joint space and traumatic arthritic changes in the talonavicular and cuneonavicular joints.
Fig. 4-C: Three months after arthrodesis.

TABLE II

COMPARISON OF NORMAL AND DENERVATED SIDES FOLLOWING STIMULATION

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	S	7.28	6.65	6.63	6.70	6.70	
9	N	7.33	7.10	7.17	7.25	7.30	7.35
	S	7.36	7.13	7.13	7.22	7.22	7.33
10	N	7.46	6.91	6.90	7.16	7.22	7.23
	S	7.24	6.89	6.78	6.62	6.58	6.60
13	N	7.28	7.13	7.10	7.24	7.32	7.32
	S	7.36	7.17	7.17	7.15	7.16	
14	N	7.45	7.32	7.38	7.40	7.40	
	S	7.37	7.15	7.13	7.10	7.10	
15	N	7.29	7.05	7.14	7.19	7.29	7.32
	S	7.24	7.00	6.97	6.91	6.98	7.00
16	N	7.41	7.22	7.29	7.40	7.43	
	S	7.31	7.09	7.14	7.10	7.13	7.16
18	N	7.33	7.10	7.15	7.18	7.26	7.24
	S	7.24	7.02	7.00	7.07	7.12	7.13

* *N* denotes normal side, *S* sympathectomized side.

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HUMERUS VARUS FOLLOWING BIRTH INJURY TO THE PROXIMAL HUMERAL EPIPHYSIS

BY LEO S. LUCAS, M.D., AND JOSEPH H. GILL, M.D., PORTLAND, OREGON

From the Shriners' Hospital for Crippled Children, Portland

Two identical and unusual cases of humerus varus have been observed in the Shriners' Hospital. A search of the literature has failed to disclose the report of a similar deformity in the relation of the head to the neck of the humerus. In both cases, the involved brachium was markedly shortened and had associated limitation of motion, especially of abduction. In one case there was a definite history of trauma to the arm at birth; in the other case no history of injury could be obtained. However, in view of the absolute similarity of these cases, the authors believe that trauma at birth was the etiological factor in each. The roentgenograms showed marked varus of the head, in relation to the shaft, of the humerus. There was marked narrowing of the neck distal to the epiphyseal plate, which was patent laterally and obliterated medially. This partial epiphyseal obliteration explains the shortening of the humerus and the varus of its neck, which resulted in greatly restricted motion. It was thought that the injury to the epiphysis probably occurred as a result of too vigorous effort on the part of the obstetrician in liberating the arm at the time of delivery. The deformity was corrected by wedge osteotomy, abduction of the arm (Figs. 2 and 3), and application of a shoulder spica. Primary union occurred in both cases, with excellent functional results.

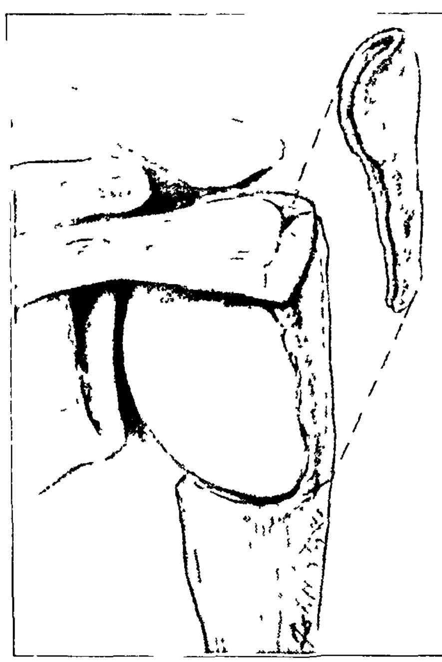

FIG. 1

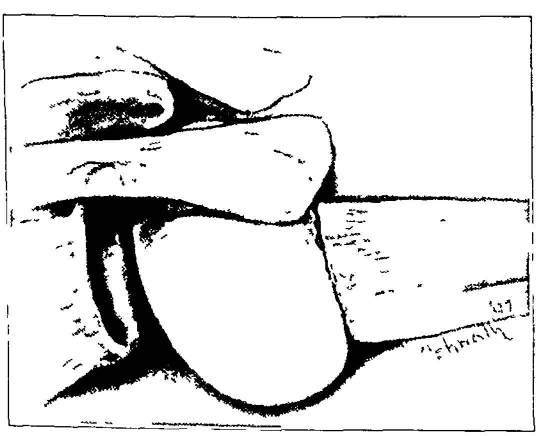

FIG. 2

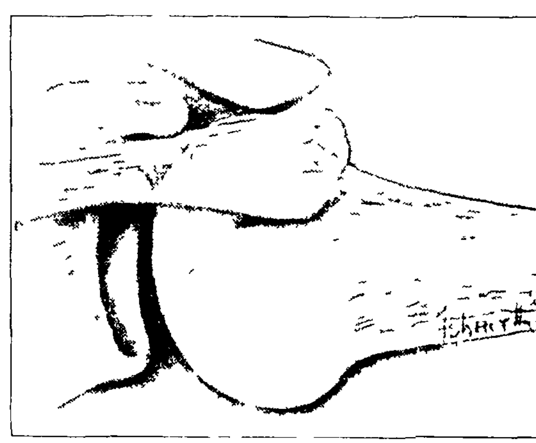

FIG. 3

Fig. 1: Drawing of the head of the humerus, before operation. The small fragment shown is the thin shell of bone, removed at osteotomy.
Fig. 2: Shows the approximation of fragments and the abduction after osteotomy.
Fig. 3: Shows the arm in position of abduction, after healing has taken place.

CASE 1509, L. M. The patient, a thirteen-year-old white male, entered the Clinic on September 6, 1934, with a complaint of disability of the left shoulder, gradually increasing since birth. The child h

tion. Therefore, maintenance of normal fluid and electrolyte balance in the joint cavity depends upon vasomotor control of the autonomic nervous system.

NOTE: The authors are indebted for advice, suggestions of value, and important assistance to F. A. Chandler, M.D., and Warren S. McCulloch, M.D.

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SECONDARY CLOSURE OF WOUNDS ASSOCIATED WITH COMPOUND FRACTURES

BY MAJOR JAMES O. BARR *

Medical Corps, Army of the United States

This report consists of an analysis of 195 cases of compound fracture, comprising a total of 289 wounds. All of the wounds under consideration communicated directly with the fracture site. The primary purpose of the investigation was to find the factor or factors most responsible for successful closure of a wound, and to determine what caused a wound to break down,—partially or completely. A further consideration was whether or not secondary closure contributed to, or helped prevent, the development of osteomyelitis in compound fractures. In this paper osteomyelitis has been classified as follows: (1) A localized infection developing in the bone at the base of the wound has been considered as localized osteomyelitis; and (2) a diffuse infection spreading through the bone beyond the traumatized area has been considered as diffuse osteomyelitis.

In general, all wounds compounding fractures, treated in the 110th General Hospital, were closed wholly or in part. A few cases were rejected on the basis of profuse purulent drainage and sloughing, excessive skin loss, and, in two cases, of *Bacillus welchii* infection. Therefore, of the 195 cases, eighteen were rejected, leaving a total of 177 cases with 262 wounds. In other words, 90.5 per cent. of the patients with compound fractures underwent secondary closure.

Preoperative preparation was based primarily on the general condition of the patient. In only a few instances was the condition serious enough to require immediate treatment. The patients were given a period of twenty-four hours in which to rest and recuperate from the rigors of travel. This was found to be important in the general care, as well as in the mental and physical effect on the patient. Patients who had severe loss of blood and plasma, particularly as a result of large, gaping wounds and large bone fractures, were given blood and plasma, as necessary.

The operative technique was essentially the same for all patients. The skin surrounding the wounds was cleansed thoroughly with soap and water, shaved, and treated with

* Formerly Chief of Orthopaedic Service, 110th General Hospital.

Fig. 5-A
G. J. Before correction.

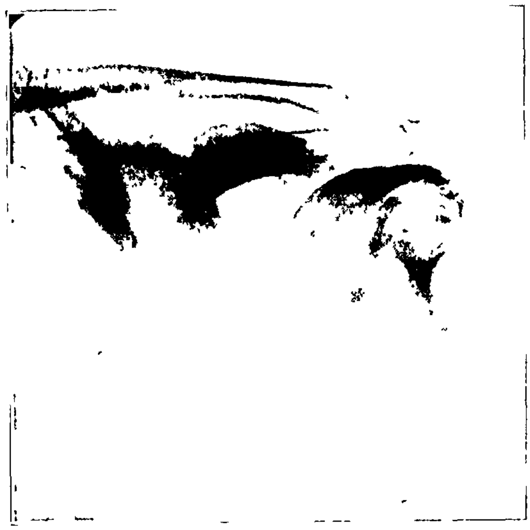

Fig. 5-C
Fifteen months after operation.

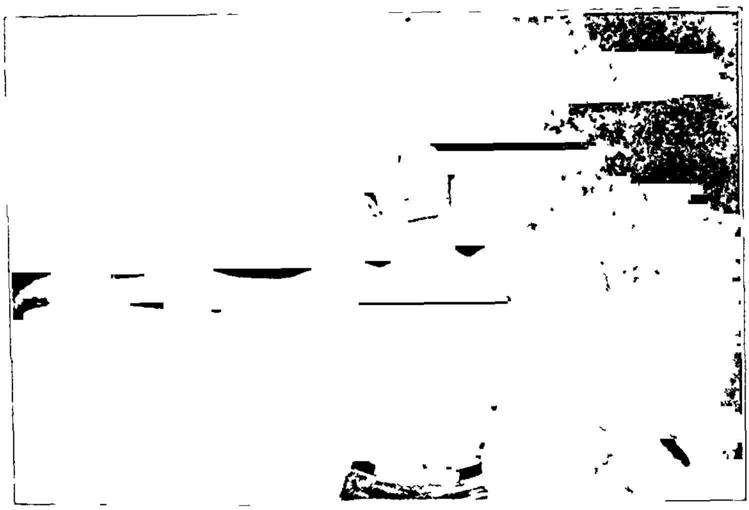

Fig. 5-B
Before correction.

Fig. 5-D
Fifteen months after operation.

platform splint was applied. After five weeks, the splint was discarded and the patient was discharged, with excellent function of the shoulder joint.

Thirteen months after operation the patient returned for a final check-up, which showed excellent function of the shoulder (Figs. 4-C and 4-D). Active abduction was possible to 160 degrees, and flexion and extension were normal. The muscle strength was good.

Case 2776, G. J. The patient was a thirteen-year-old white boy, who entered the Clinic on September 2, 1943, with a complaint of shortening and limitation of motion of the left brachium. His parents stated that the deformity had gradually increased since infancy. No definite history of trauma, either at birth or thereafter, was obtained.

Physical examination showed marked shortening of the left brachium, as compared with that on the other side. Marked limitation of motion about the shoulder joint was observed, and passive abduction was possible only to 80 degrees. Considerable weakness of the shoulder muscles was present. Roentgenograms disclosed closure of the proximal epiphyseal plate on its medial aspect and patency laterally (Fig. 5-A). Marked shortening and varus of the humeral neck were present.

On October 20, 1943, a wedge osteotomy of the area of the deformity was done. While the head was held in position, the arm was abducted to 90 degrees with resultant correction of the deformity. A left shoulder spica was applied while the arm was in this position. Two weeks after operation, the cast was bivalved and removed. The arm was placed on a platform splint in 90 degrees of abduction, and physical therapy was started. One month after operation the splint was removed. At this time the boy was able to abduct his arm actively to 170 degrees; rotation, flexion, and extension showed minimum restriction.

The patient returned fifteen months after operation for a final check-up, at which time he had a complete range of painless motion and normal muscle strength (Figs. 5-C and 5-D).

TABLE II

RELATION OF HEMOGLOBIN DETERMINATION TO PERCENTAGE OF WOUND CLOSURE

Hemoglobin (*Per Cent.*)	Closure of Wounds (*Per Cent.*)											Total No. of Cases	Closure of 90 Per Cent. and Over (*Per Cent.*)
	100	90	80	70	60	50	40	30	20	10	0		
30 to 39	2	1			1							4	75*
40 to 49	1	2				1						4	75*
50 to 59	6	2	3	1	4		1				4	21	38
60 to 69	28	2	3	2	2	3					2	42	71
70 to 79	34	5	2	1								42	93
80 to 89	88	7	2		1						2	100	95
Totals	159	19	10	4	8	4	1				8	213	83

* This group is considered not large enough to be significant.

over. On the other hand, of 103 comparable wounds that were closed without either drug, ninety-one (88 per cent.) remained healed 90 per cent. or over.

These statistics show definitely that there was no appreciable difference in wound healing in the cases treated with sulfadiazine and penicillin and in those in which no chemotherapy was given. It should be mentioned, however, that wounds receiving no chemotherapy were usually small, and that the general condition of the patients was good. On the other hand, enough wounds, both medium and large, held satisfactorily without hemotherapy to make the author believe that chemotherapy, administered during the rocess of closure, had little or no advantage. All patients received sulfadiazine during acuation, however, and many had penicillin in addition.

rythrocyte Count and Hemoglobin

In correlating the effectiveness of closure with the blood picture of the patient on admission, it was seen that, in general, the better the red-blood-cell count and the hemoglobin value, the better chance the patient had of a final closure of 90 per cent. or over. The estimations of the red blood cells and hemoglobin were made separately, and closely paralleled each other in their conclusions (Tables I and II).

Location of the Wound

As work progressed on these secondary closures, it was soon evident that the anatomical location of the wound was an important factor in determining not only the wounds which could be closed initially, but also the final percentage of closure. The best results were obtained in regions where there was an adequate amount of subcutaneous tissue and good elasticity or mobility of the skin; on the other hand, in areas where the cutaneous tissue was of poor mobility, the mechanical disadvantage thereby created caused a greater diffi-

TABLE III

ANALYSIS OF TYPE OF DISCHARGE FROM WOUND

Discharge	Closure of Wounds (*Per Cent.*)								Total	Closure of 90 Per Cent. and Over (*Per Cent.*)
	100	90	80	70	60	50	40 to 10	0		
Serous	66	4		1		1			72	97
Serosanguineous	99	11	5	3	4	3		4	129	85
Seropurulent	23	9	6	4	5	3		4	54	60
Purulent					1			3	4	0
Totals	188	24	11	8	10	7		11	259	82

TABLE I

STIMULATION RECOVERY CURVE ON DOG No. 6 *

Time (*Minutes*)	pH Determinations			
	Right Knee	*Right Vein*	*Left Knee*	*Left Vein*
2		....	....	7.46
4	7.38	....	....	....
5		7.49	....	....
6	7.46	.	....	....
7	....		7.43	....
8	....	7.49		....
9	....		7.43	...
10	....			7.50
11½	7.46			7.51
13–14	Stimulation of left femoral nerve for 1 minute			
14½	.	....	7.28	....
15½	.	...		7.25
16½		.	7.28	
17½		..		7.45
18		. .	7.36	....
19	.	. .	7.38	....
19½			7.40	....
20	7.44	...		....
20½				7.54
21		7.47		.
21½–22½	Stimulation of right femoral nerve for 1 minute			
23½	6.92		...	...
25	....	7.11	....	...
26	6 86		.. .	...
27		7.19	.. .	....
28	6.78		....	....
29½		7.37	....	....
30½	6.90		....	....
32	7.11		....	....
33	7.11		....	....
34		7.49	....	....
35½	7.16	.	....	....
36½	7.16	. .	....	....
37	Perivascular sympathectomy of left femoral vessels begun			
39			7.44	.
40½	7.10	..		7.46
41	Sympathectomy completed			
42–43	Stimulation of left femoral nerve for 1 minute			
43½	....	....	7.10	7 20
45	.. .	...	7.10	
46	....	..		7.40
48½	...	..	7.10	
49	.	.	7.08	
51	.	. . .		7.43
53½	.		7 06	..
54–55	Massage of left knee for 1 minute			
55½	....	.. .	7.10	...
57	....	...		7.40
58	.. .	....	7.13	....
63	.	...	7.18	....
64	7.15	7.43	....	....

* Perivascular sympathectomy of right side was carried out on April 3; final experiment was done on April 10, with nembutal as the anaesthetic.

EXPERIMENTAL STUDIES

The method of perivascular sympathectomy, as applied to the study of pH changes in synovial fluid, has the following purposes: The operation modifies circulatory control distal to the surgical site, since vasomotor impulses normally conducted by the fibers are interrupted, thus modifying the water and electrolyte balance between joint cavity, tissue fluids, and vascular tree[1]. Predominantly, the chronic result was permanent dilatation of the capillaries, presumably with damage to the wall and flow of transudate into the tissues.

The operation was performed one week in advance of the observations on synovial-

necrotic material was more thoroughly performed. In the first series, diffuse spreading of infection beyond the boundaries of the fracture site did not develop. In the second series, there was one case (in a tibia) in which the inflammatory process spread beyond the fracture site and became a typical diffuse osteomyelitis. In many of the cases in which a localized infection developed, this cleared satisfactorily and the cavity became granulated, partially or entirely, by the time the patients were transported to the United States.

The author believes that the value of secondary closure of compound fractures is definitely established. By closing the wound rather than allowing it to fill in with granulations, the contour of the limb is re-established; the long period of granulation and skin-grafting is eliminated; and the patient's stay in the hospital is considerably shortened. Also of importance is the fact that fibrosis and fixing of the soft tissues around the fracture site are minimized. In large gaping wounds, where the patient is losing large amounts of protein through profuse drainage, secondary closure stops this serum loss and remarkably improves the general condition of the patient. In addition, secondary hemorrhages, which had previously been a serious complication, practically disappeared.

The wounds which are the most difficult to close initially and the most difficult to keep closed are those in locations where the skin is tight and of poor mobility, and where there is little subcutaneous tissue. Wounds parallel in location—for example, on both sides of the arms or legs—are also difficult to close, and remain closed poorly, because the loss of skin is in such a position that too much tension is necessary to close both wounds. A procedure which has been used satisfactorily to combat this condition was to close one wound and place the limb in a cast. It was found that, in about a week, the oedema had subsided enough so that the second wound could be closed with relative ease. It has been found possible to tie stay sutures under considerable tension, and the usual result is to find, the next morning, that much of the oedema in the wound has subsided and the stay sutures have laxed to such a degree that they may have to be tightened.

CONCLUSIONS

1. Chemotherapy is probably of little or no benefit during the actual process of closing wounds associated with compound fractures.
2. It is quite conclusive that, the better the blood picture, the better chance a patient has for his wounds to heal.
3. It is believed that the age of the wound, in itself, has no particular significance with relation to whether or not the wound remains healed.
4. The anatomical location of a wound is the most important factor both in the initial closure of the wound and in the final result after the wound has been closed. Wounds in the leg, particularly the lower third of the leg and around the ankle and foot, present the greatest number of partial and complete breakdowns.
5. The type of wound discharge is probably not of great importance in the prognosis of secondary closures. Those wounds which present a seropurulent or purulent discharge do not heal so satisfactorily as those presenting a serous or serosanguineous discharge.
6. No one factor alone can be cited as being of prime importance in breakdowns. However, the combination of anatomical location of the wound, the general physical condition of the patient on admission, and the type of wound discharge have been shown to be of the utmost importance in the final outcome of these wounds.
7. The occurrence of diffuse osteomyelitis after the closing of compound fractures is not to be feared, and the benefit derived from closing the wounds far outweighs the slight (0.5 per cent.) chance one takes of diffuse osteomyelitis.

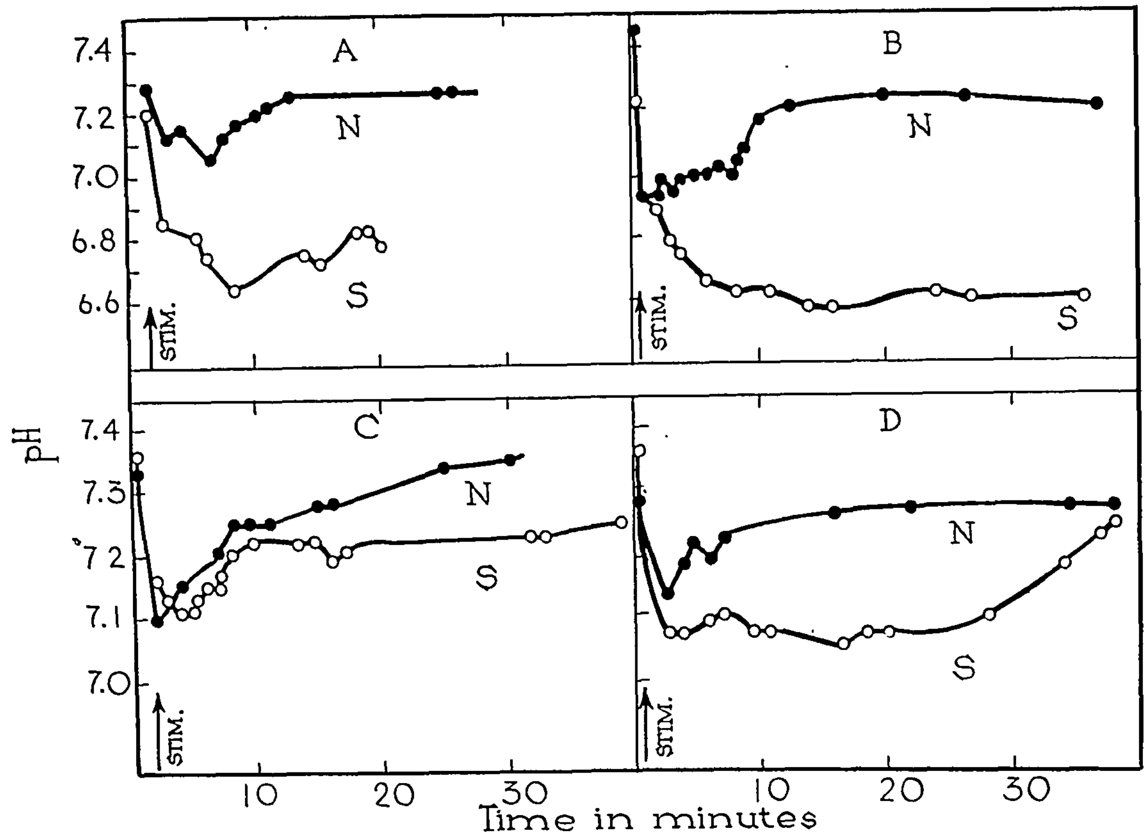

FIG. 2
Stimulation recovery curves of pH. *N* denotes normal side, *S* sympathectomized side.

In ten additional experiments, effects of other variables—such as joint massage or injection of weak acids or bases—were compared on the normal and denervated sides. In these cases the effect of massage on the two knee joints was determined on the resting, unstimulated joint, with the pH at a steady level in the physiological range (approximately 7.2 to 7.5). Its effect was also studied immediately after stimulation and at various other times during the recovery curve.

RESULTS

A. *Recovery Curves*

Four sets of stimulation recovery curves are shown in Figure 2. These have been selected from all the observations to illustrate the range of effects on the normal and sympathectomized sides, and the various types of response that have been observed. The effects of nerve stimulation on blood pH also have been noted on both sides in these animals. In all cases the pH in the femoral veins fell sharply to a minimum in from one to two minutes, and rapidly recovered, approaching the resting level within five or ten minutes. Because of this relatively constant effect on both sides, differences in the recovery curves of the blood pH cannot be related to differences of response in right and left knee joints. The recovery of blood pH was invariably much more rapid than the recovery of joint pH, on both sides.

In each of the four sets of comparative curves in Figure 2, the time origin is taken as approximately the time of beginning of the stimulation. Actually, the two femoral nerves were stimulated at different times, the second stimulation being applied from fifteen to thirty minutes after the first in order to allow time for partial or complete recovery on the previously stimulated side. The curves are drawn to the same time origin in order to clarify the comparisons. In each of the four normal recovery curves in Figure 2, the initial

difference in length was inconsequential, since the grafts were all of the same width and were of full-thickness cortical bone. These grafts were cut from the subcutaneous surface of the tibia; and, in one group, the graft was removed in its entirety and replaced, in order to study the effects of replacing cortical bone grafts in the tibia. In the second group, a cortical plug was removed and bone taken from the ilium was substituted. This iliac bone contained its two cortical surfaces. In these instances the cancellous bone was placed in contact with the medulla and the subcutaneous surface of the tibia. In a third group, cortical grafts from the tibia were removed and not replaced. These served as the controls. Into defects created by the removal of bone from the ilium, cancellous bone and cortical bone were inserted to study their comparative reactions.

The animals were anaesthetized with evipal, given intraperitoneally in the proportion of 110 milligrams to each kilogram of body weight. Supplementary novocain was sometimes required. Death from anaesthesia occurred in a few animals. Osteotomes and motor-driven saws and drills were used to section the bone, and closure of the wounds was effected by cotton sutures. In order to prevent the animals from kicking and breaking their legs, both sciatic and femoral nerves were infiltrated with novocain in some cases. In others, neurectomies were performed. Fixation was secured by casts on both hind legs, extending from the toes to the groin. This method of immobilization did not entirely prevent breaking of the tibia, but fracture was less frequent. However, plaster fixation of the hind legs of a rabbit interferes with its normal feeding habits, for apparently there is a relationship between the use of the hind legs and digestion. Consequently, a high proportion of our rabbits ate very little, and many died of starvation. For those that survived, feed consisted of green cauliflower leaves, carrots, and prepared pellets which constitute a diet containing the necessary vitamins for normal rabbit development. The animals were housed in small cages, and those that did not die of starvation were sacrificed at intervals of four, seven, ten, sixteen, twenty-one, and thirty-five days; and autopsies were performed immediately. From the fifty-two animals originally prepared, forty-two grafts were obtained for study as follows:

Cancellous bone—7
Cortical bone with periosteum—5
Cortical bone without periosteum—8
Cortical and cancellous bone—12
Controls—10.

Discussion: In this group of experiments we found a great difference in the behavior of cortical and cancellous bone. In the former, there is very little difference between the action of grafts with or without periosteum. Moreover, in this series of experiments, few of the grafts with periosteum attached showed new-bone formation from the periosteum. In the graft bed, where the periosteum had been reflected without disturbance of its circulation, there was profuse new-bone formation. At the end of ten days, the cortical graft showed evidence of death by absence of cells in the lacunae. The Haversian systems were invaded by new vascular granulation tissue, while the surface of the graft was being absorbed with evidence of osteoclasts in Howship's lacunae. The death of bone, its absorption and invasion by granulation tissue, and a process of creeping substitution with new-bone formation, as described by Phemister, were clearly displayed. On the other hand, in the cancellous graft at ten days, revascularization was much more rapid, and if the trabeculae were reached by the new granulation tissue by that time, a considerable number of them lived to produce new bone. In those parts of the graft where nutrition was delayed beyond the ten-day period, death usually took place. Even with death of the trabeculae, revascularization was more rapid than in the case of the cortical bone.

applied to extremities with intact autonomic innervation. It was assumed that the effect depended upon facilitation of the exchanges of fluid and electrolytes between joint cavity, tissue fluids, capillaries, and lymphatics. In the present investigation a comparison of the effects of massage on the normal and sympathectomized sides has shown some interesting points.

The results of four massage experiments are shown graphically in Figure 3. They are typical of a more extensive series, including ten animals. When a normal resting joint with a pH in the range of 7.2 to 7.5 is massaged for one minute, the pH usually falls by about 0.1, but recovers within a minute or two. The comparable effect on the sympathectomized side is usually small or negligible (Fig. 3, *A* and *C*). When, however, the massage is applied to a joint, the pH of which has been previously displaced by femoral-nerve stimulation and muscle contraction, as in the pH recovery experiments, the effects are quite different on the two sides. When the knee on the normal side is massaged within a few minutes after stimulation, the pH recovery is very rapid (Fig. 3, *B* and *D*). Massage applied to the knee joint on the sympathectomized side shortly after femoral-nerve stimulation is found, on the other hand, to lower the pH even further (Fig. 3, *B*). This contrast between normal and sympathectomized sides is found also when massage is applied later in the recovery phase. Figure 3 (*A*, *C*, and *D*) illustrates the types of effect that were found. In *A*, massage applied on the normal side ten minutes after stimulation increased the pH moderately. In *C*, when applied on the normal side twenty minutes after stimulation, it increased the pH moderately after a slight fall. On the other hand, when the knee joint on the sympathectomized side was massaged twenty or thirty minutes after stimulation, the result was generally a sharp fall of pH. A similar drop of pH occurred when that joint was massaged within a few minutes after stimulation (Fig. 3, *B*).

DISCUSSION

The experimental results show consistent differences between the effects of nerve stimulation on the joint pH of the normal and sympathectomized sides. These differences are most pronounced with respect to the rate of recovery of pH in the resting period following stimulation. Response to massage is also contrasted on the two sides. On the sympathectomized side, recovery of pH is relatively slow; and often there is none. On the same side, the pH usually falls when the joint is massaged at any time subsequent to nerve stimulation. These responses contrast markedly with those on the normal side.

As has been pointed out, these pH changes do not correspond to changes in the blood pH, as observed in the femoral vein. In all cases, blood pH recovers rapidly on both sides after an initial sharp drop following stimulation. Therefore, exchange of fluid and electrolytes between capillaries and joint fluids is not sufficient to account for the observed differences.

Is it possible to relate these differences to other changes which occur following perivascular sympathectomy? As has been pointed out, these changes include a disturbed balance between tissue fluid and blood, and an impaired venous return. Both factors are related to pH and electrolyte balance of the joint fluid, because of exchanges with the tissue fluid. On hydrodynamic principles, fluid exchanges between blood, tissues, and joint cavity depend on pressure gradients. From this point of view, the poor recovery following stimulation on the sympathectomized side is related to the lowered pH following massage. During muscle contraction, acid metabolites are formed. Because of the circulatory imbalance, they accumulate in the tissue fluids. Poor venous return from the joint and exchanges of tissue-fluid electrolytes with the joint fluid delay the recovery of the joint pH during the resting period. Massage lowers the joint pH by forcing the acidic tissue fluid into the joint cavity. On the normal side, massage increases the pH by facilitating exchanges with both blood and tissue fluid, the pH of which recovers rapidly after stimula-

plaster-of-Paris was found to be unnecessary. Across the line of excision, grafts of cancellous or cortical bone were placed, one vertically and two horizontally, on the anterior and lateral surfaces, respectively. In this group, grafts were also placed in the beds which had been prepared. In addition, the defects in the ilium created by removal of the grafts were used for the study of cortical and cancellous grafts laid in beds of pure cancellous bone.

Forty-five dogs were operated upon, thirty-two of which were used for study. From the entire group of dogs, sixty-seven grafts were obtained. The types of grafts were as follows:

Cancellous bone—16
Cortical bone from the tibia with periosteum—19
Cortical bone without periosteum—14
Controls—18.

The grafts were divided into the following sub-groups: (a) cortical bone with periosteum in one leg as against cortical bone without periosteum in the other; (b) cancellous iliac bone in one leg as opposed to cortical bone with periosteum in the other; (c) controls as opposed to cancellous iliac bone; and (d) controls as opposed to cortical bone without periosteum.

In this group of experiments, specimens were obtained at five, ten, fifteen, twenty-one, forty-two, and sixty days, respectively. The grafts removed for study were those which had been fitted across the front of the line of excision and into the trough created by the osteotomy of the tibial tubercle.

Discussion: The study of the cancellous and cortical grafts revealed the same changes observed in the first two series of experiments. Cortical bone dies, is gradually absorbed, and then is replaced. A considerable part of the cancellous bone grafts live to form new bone. In those parts of the bone which are not revascularized sufficiently early, the trabeculae die, and the process from then on is the same as in the cortical bone. With revascularization, new bone forms, the old trabeculae are absorbed, and gradually the original pattern of cancellous bone is restored. These experiments offer support for the use of cancellous bone as a grafting material at the ends of the long bones, or in fusion of joints where the bone of the host is of a cancellous type. Cancellous grafts placed in intimate contact within a bed of vascular cancellous bone are rapidly invaded by vascular granulation tissue. This affords nutrition sufficiently early for promoting the growth of the many osteoblastic cells lining the trabeculae over a wide area, with the resulting formation of new bone. As a consequence, there is a rapid incorporation of the graft with union to the host. Cortical grafts placed in cancellous bone live only on their endosteal surface, which is of a relatively small area when compared to the endosteal surface and the numerous branching trabeculae of cancellous bone. Furthermore, the major part of a dense cortical graft must be invaded and replaced. Union is comparatively slow, and its deeper portion rarely becomes an intimate part of its host. It remains as a strut of cortex lying in the surrounding cancellous bone.

These changes at the line of excision of the joint are of interest. Immediately after excision, a blood clot forms between the ends of the bone. This is replaced by vascular granulation tissue. Following in the wake of this granulation tissue, new bone is formed, which is evidenced by trabecular deposits of collagen, which are lined by osteoblasts. Finally there is a complete replacement of the original area of the excision with bone of a cancellous pattern.

Series IV

In this series of eight dogs, the spinous processes were exposed from the first to the seventh lumbar vertebra. The spinous process of the seventh lumbar vertebra was completely excised to be used as a graft, as explained later. The spinous processes from the

iodine and alcohol. The skin edges were freshened, care being taken to remove as little skin as possible. Skin flaps were undermined around the wound, until it was obvious that further undermining would relax no more skin. Reflection of the flap was done in the plane of cleavage between the subcutaneous tissue and the deep fascia overlying the muscles.

The depths of the wounds were treated in the following manner: Those which had a layer of debris and slough were debrided and cleaned until fresh, healthy tissue was present. In the earlier cases, no fragments of any size which were still attached and in relation to the fracture site were excised. Later it was found that wounds progressed more favorably if considerable care was taken to remove all debris, such as the comminuted bone fragments and foreign bodies in the depths of the wounds. As the last step, the wound was irrigated thoroughly with normal saline. Stay sutures of bone buttons and steel wire were used in most of the cases. These were placed in such a manner that the buttons were at least an inch from the wound edges; it was found that they could be tied with considerable tension without causing skin necrosis. The skin edges were approximated with interrupted sutures of heavy silk, placed not closer than one-half inch apart. A small rubber tissue drain was placed beneath the skin of each wound, and was removed on the third day. No attempt was made in any case to obtain a cosmetic closure.

The various factors which were considered of importance in this type of secondary closure were carefully recorded and analyzed statistically. These charts have been omitted for the sake of brevity. In order to analyze the results statistically, a wound which stayed closed 90 per cent. or over was arbitrarily selected as a base for estimating the percentage of closure. In estimating the percentage closure of wounds, the approximation of skin was used as a basis; but in a great many cases where the skin edges broke open partially, the soft tissue beneath remained closed and kept the fracture site covered.

RESULTS

It was possible at the time of operation to close 227 of 254 wounds 90 per cent. or over. Of these, 213, or 93 per cent., remained closed 90 per cent. or over.

Effect of Chemotherapy

The value of administering chemotherapy during the closure of these wounds was investigated, with surprising results. The cases were grouped into (1) those receiving penicillin alone, (2) those receiving sulfadiazine alone, (3) those receiving both penicillin and sulfadiazine, and (4) those receiving no form of chemotherapy. Only four cases received penicillin alone; in all of these the wounds healed, but the number of cases is considered not large enough to be significant. Of seventy-six wounds, the closure of which was accompanied by the systemic administration of sulfadiazine, sixty, or 79 per cent., remained closed 90 per cent. or over. Of fifty-two wounds closed in conjunction with the administration of both penicillin and sulfadiazine, forty (77 per cent.) remained closed 90 per cent. or

TABLE I

Relation of Erythrocyte Count to Percentage of Wound Closure

Red Blood Cells (*Millions*)	Closure of Wounds (*Per Cent.*)											Total No. of Cases	Closure of 90 Per Cent. and Over (*Per Cent.*)
	100	90	80	70	60	50	40	30	20	10	0		
1.0 to 1.95	3	2		1								6	83*
2.0 to 2.95	10	2	4		3	1	1				3	24	50
3.0 to 3.95	51	5	3	2	1	3					3	68	82
4.0 to 4.95	96	8	3		3						2	112	93
Totals	160	17	10	3	7	4	1				8	210	84

* This group is considered not large enough to be significant.

Fig. 1

Iliac graft at sixty days, with death of the graft because of poor contact with its bed. There are no cells on the surfaces of the trabeculae.

Discussion: In this group, sixteen specimens were secured; they may be divided into two groups,— those in which the grafts were maintained in good position, and those where displacement of the graft occurred. In the latter cases, the iliac grafts showed death with disappearance of the bone cells from their lacunae, slow revascularization, and the delay of the formation of new bone upon the dead trabeculae (Fig. 1). These findings emphasize the importance of maintaining accurate contact between the graft and the graft bed, regardless of the type of graft utilized. Some interesting findings were observed in studying the graft bed in the divided tibia. Cortical bone at the site of the osteotomy showed widening of the Haversian systems with early revascularization and formation of new-bone trabeculae. There was also absorption of bone by osteoclasis. This is the process of osteoporosis at the end of the fragment, which occurs after fracture. Furthermore, the periosteum, which had been reflected without disturbance of its circulation, proceeded with profuse formation of new bone, in which the trabeculae were lined up in a plane at right angles to the old cortex. In one case where there was poor fixation of the graft with no pressure due to weight-bearing, specimens showed the same changes at sixty days as at

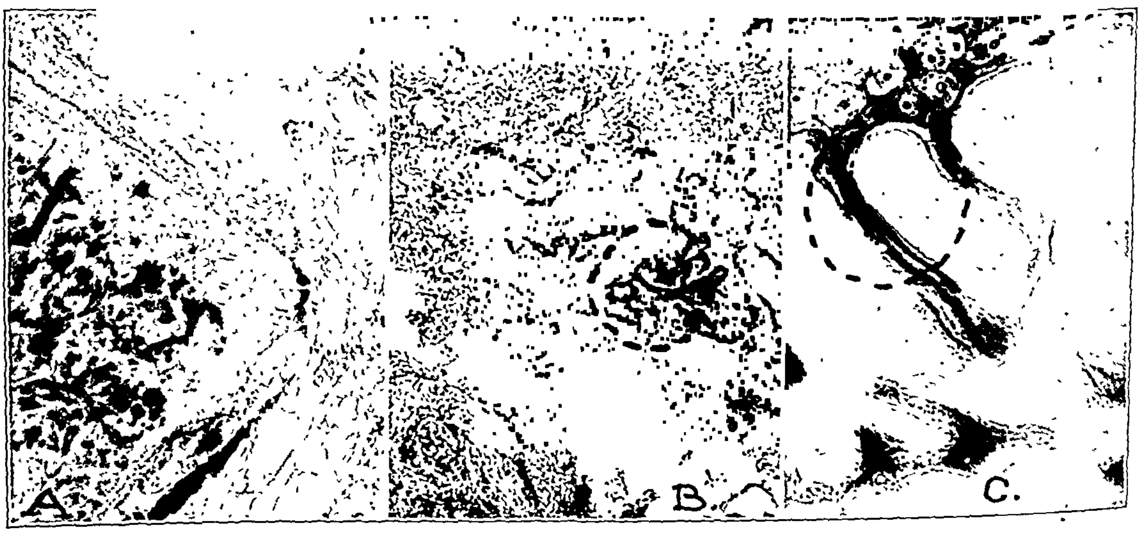

Fig. 2

Comparative studies at five days of cortical, cancellous iliac, and rib grafts in a dog.

A: Cortical bone with no evidence of revascularization.
B: Cancellous iliac graft with formation of new trabeculae.
C: Rib graft, showing trabeculae and cells on its surface, as disclosed in Fig. 3, C^1.

culty in the initial closure and caused many wounds to break down, partially or completely. Thus it was found that poor results were obtained in the leg and foot. Here only 76 per cent. and 82 per cent., respectively, of the wounds remained healed 90 per cent. or over, whereas the results obtained in all other wounds (exclusive of the hip) were successful by this standard in 95 per cent. of 175 cases. These figures show that the tension factor is of great importance, not only in the initial closure of the wound, but also in the ability of the wound to remain closed and heal by first intention.

Nature of the Discharge

It was the author's impression early in the series that the type of discharge presented by these wounds on admission affected their ability to heal without complication. Therefore, wounds were tabulated according to the type of discharge,—namely, serous, serosanguineous, seropurulent, and purulent. Table III shows conclusively that wounds having seropurulent or purulent discharges did not heal nearly so well as did wounds presenting serous or serosanguineous discharges.

Time of Closure

It was at first believed that the earlier a wound was closed, the better the results would be. This is true in making it possible for the surgeon to close the wound initially, because the skin and underlying soft tissues have not had time to become fixed. This fact is of the utmost importance, and cannot be stressed too strongly. However, the figures show that the time element in itself does not affect the healing processes of the wound after its closure.

Failure of Closure

There were nine complete failures. Seven of the nine occurred in wounds below the knee; six of these occurred in patients having an erythrocyte count of 4,000,000 or below, four of whom had shown a hemoglobin of 70 per cent. or below; and five of the nine had seropurulent or purulent discharges from the wounds. Although no definite conclusions can be drawn from these facts, it is evident that a combination of the anatomical location, the character of the wound discharge, and the general blood picture of the patient is of prime importance in determining the final result.

Extensive Comminution

When these secondary closures were begun, the possibility that osteomyelitis might develop underneath the closed soft tissues was considered. It was soon evident that osteomyelitis, in the usual sense of the word, was not going to be a problem. However, it was noticed that certain wounds, particularly those which had severe comminution in a portion rich in medullary bone, occasionally broke down and drained. This drainage at first was usually a reddish-brown, odorless slough, which subsequently changed to thick, creamy, light-yellow discharge, having the odor of necrotic bone and often containing small particles of dead bone. This open and discharging wound became secondarily infected with outside contaminants, resulting in a localized bone infection or a localized osteomyelitis, depending upon how it is classified. In only a few cases did the wound show signs of acute inflammation before opening and discharging. The author believes that the majority of these breakdowns begin with sloughing of cortical and medullary bone, which, on disruption of the wound, becomes secondarily infected by external contaminants. It is possible that, by more thorough removal of these traumatized bone fragments, the incidence of this process can be decreased.

In the first series of cases (September to December 1944), this localized bone infection occurred in 15.2 per cent. of the cases, while in the second series (January to March 1945) it occurred in 9.5 per cent. This decrease in incidence was probably due to two factors, the most important being that the second series of cases was composed of less severe wounds with less traumatization of bone, and, second, that removal of bone fragments and other

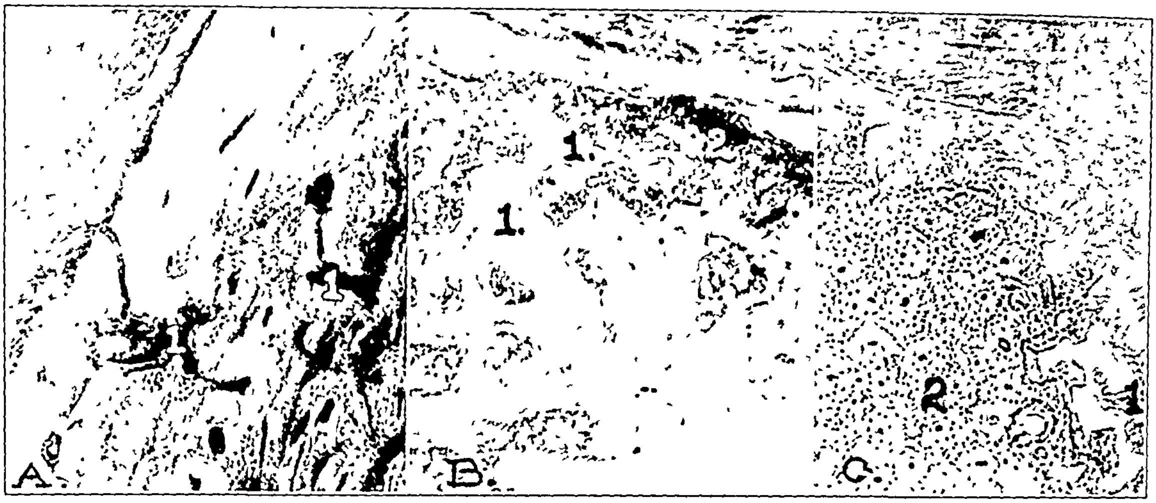

Fig. 4

Comparative studies at twenty-one days of cortical, cancellous, and iliac grafts in a dog.

A: Cortical graft, showing granulation tissue invading the superficial Haversian system at areas marked *1*.

B: Cancellous iliac graft with new-bone formation, as shown by increased width of old trabeculae at *1*, and formation of new trabeculae at *2*.

C: Rib graft shown at *2*; formation of new trabeculae at *1*.

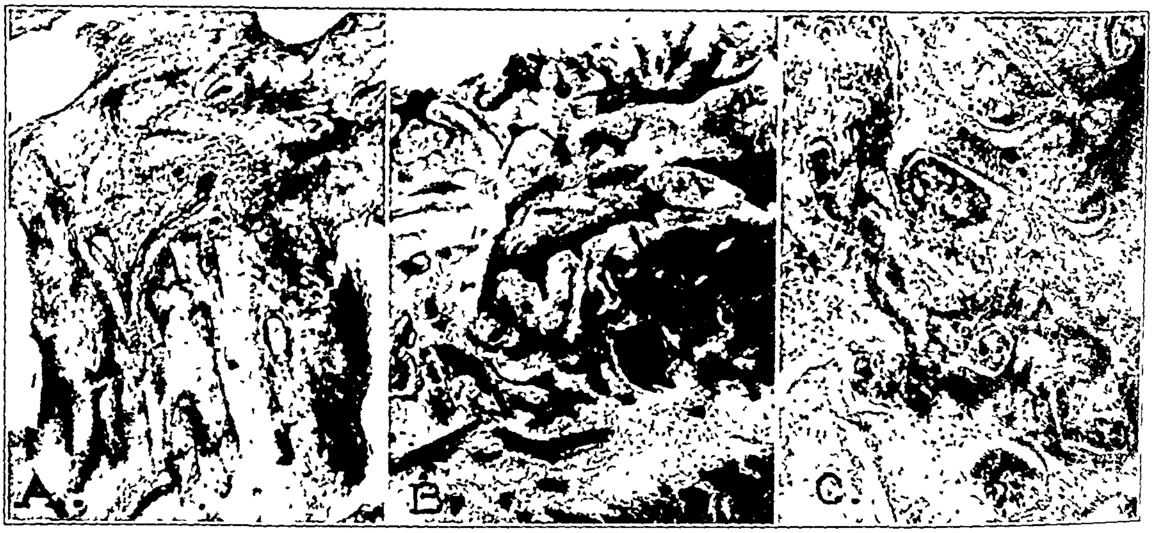

Fig. 5

Comparative studies at sixty days of cortical, cancellous iliac, and rib grafts.

A: Cortical-bone graft, showing advanced revascularization and the process of creeping substitution.

B: Cancellous bone, showing advanced stage of new-bone formation.

C: Rib graft in advanced stage of new-bone formation.

RESULTS OF EXPERIMENTS

In the following paragraphs are summarized our experimental findings.

In our earliest specimens of iliac bone, seen at three days after it was placed in the site of an osteotomy in the upper end of the tibia, the intratrabecular spaces were filled with fibrin and red cells; this was secondary to the trauma caused by removal of the graft. At the margins of the graft, very early vascular granulation from the graft bed was seen. At five days, the new granulation tissue was observed growing across from the graft bed to the graft. Just behind this granulation tissue of the graft bed, there was early proliferation of osteoblasts upon the old trabeculae, and still deeper toward the graft bed new trabeculae were forming (Figs. 2, *B* and 3, *B*[1]). At ten days the granulation tissue had thoroughly invaded the average small graft, while in the larger graft, vascularization was incomplete. Furthermore, after ten days there was fresh evidence of incrustation and formation of new

THE EVALUATION OF CORTICAL AND CANCELLOUS BONE AS GRAFTING MATERIAL

A Clinical and Experimental Study * †

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In this article the writers wish to record the results of their experiments on animals, which were made with the idea of determining the relative values of cancellous and cortical bone as grafting substances. Furthermore, they desire to present their findings regarding the use of either type of bone or both types jointly in various conditions encountered by the orthopaedic surgeon. These findings are based on experimental work, microscopic studies of human grafts, and clinical observations. A review of the extensive literature on the subject of bone-grafting and the various theories of bone formation will not be attempted in this article. However, mention should be made of the pioneer work in this field of Gallie, Phemister, and Albee, whose publications remain outstanding contributions to the fundamental knowledge of bone-grafting. In the text, reference is made to various articles, some of which contain complete bibliographies on various phases of the subject.

Experiments on animals, which were made possible by a grant from the National Research Council, extended over a period of three years. A detailed description of these experiments, which were carried out by one of the writers (E. R. S.), will be given in later publications. There were five groups, as follows:

1. Cortical defects, which were made in the shaft of the tibia, were filled by grafts of both cancellous and cortical bone.
2. Complete resection of a segment of the middle of the shaft of the radius was done, and the defect was filled by grafts from the cancellous portion of the ilium, the rib, or the cortex of the tibia.
3. Excision of the knee joint was performed, with supplementary grafts of cortical and cancellous bone.
4. Iliac bone, cortical bone, and bone from the spinous process or the rib was placed in split spinous processes.
5. Cancellous iliac bone was placed at the site of a transverse osteotomy of the tibia.

(Note: Controls were used in all of the groups of experiments.)

Series I

In the first group, rabbits were used. Most of the rabbits were young females, from four to six weeks old at the time they were acquired. They were kept for three or four weeks before operations were performed. Both tibiae were used. Cortical grafts cut from the tibia varied in length from 0.8 of one centimeter to 2.8 centimeters, the width of each graft being approximately one-half the breadth of the tibia. In this series, because of complications consisting of fractures of the tibia and infected wounds, there were not sufficient animals for final comparative studies regarding the reactions in varying lengths of grafts. We were forced to group all of our grafts, therefore; and the results convinced us that the

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† The experimental work described in this paper was done under a contract between the Office of Scientific Research and Development, Washington, D. C., and the University of California.

our specimens at 100 days, the cancellous bone graft from the ilium was difficult to outline. In one specimen at one year, evidence of the graft no longer existed, except as indicated by cortical thickening at the junction of the graft and the graft bed. In this specimen, reformation of the medullary canal had occurred at the site of the osteotomy. In those iliac grafts where contact was not established or maintained, revascularization was delayed and the graft usually died and behaved much the same as cortical bone. Finally the new granulation tissue invaded the clot, which separated the graft from its graft bed, and the dead trabeculae were gradually replaced.

At five days, the cortical grafts placed in a cancellous bed were surrounded by a narrow fibrin clot, through which grew new granulation tissue much the same as that described in the case of the cancellous-bone graft (Figs. 2, *A* and 3, *A*¹). These grafts with periosteum attached showed no periosteal proliferation, nor was there evidence of revascularization. Occasionally a finger-like process of granulation tissue from the graft bed was seen, which had grown into contact with the graft. The nuclei of the graft were still visible, and showed no evidence of shrinking. In the graft bed there was a very early proliferation of the endosteum with occasional formation of new trabeculae. The graft bed, being of the cancellous type, showed proliferation with incrustation of the old trabeculae, and the formation of new trabeculae which appeared to be growing out of the primary trabeculae. In some cases there was a feeble endosteal proliferation which did not, however, attach the graft to its bed. At ten days, granulation tissue could be seen growing through the clot and a row of osteoclasts lying in Howship's lacunae along the margin of the graft. Its surfaces showed granulation tissue growing into its widened Haversian systems. At this time also the nuclei had disappeared from the lacunae of the graft. Occasionally we saw evidence of replacement by new bone in the most marginal of the Haversian systems. At fifteen days, the graft was almost enclosed by new trabeculae growing from the graft bed, with some fusion apparent between the graft and its bed. Revascularization had increased, the marginal Haversian systems were wider, and there was a slightly broader ring of new bone at the most marginal of the Haversian systems. At twenty-one days, in the cortical graft the findings were practically identical with those at ten days, except that there was an increase in revascularization and replacement (Fig. 4, *A*). In some of our grafts we observed periosteal new-bone formation at this stage, and osteoclasts along the bone surface were still apparent. At twenty-one days, there was evidence of good union of the graft with the graft bed. It is interesting to note here that bone from the graft bed grows out toward the graft through the new vascular granulation tissue, but when it comes into contact with the dead cortical bone, it grows parallel with its surfaces. At forty-two days, the cortical graft was firmly bound to the graft bed by a layer of trabeculae, while at sixty days, its replacement by new bone was still gradually taking place (Figs. 5, *A* and 6, *A'*). In our experiments, cortical grafts, with and without periosteum, behaved in the same way, and in the latter type there was better evidence of proliferation with the exception of a few instances.

Changes in the rib graft were very similar to those seen in cortical bone. They were in an active process of revascularization and replacement, and did not show pronounced growth of new bone from the graft itself. In the few cases of the rib graft that we were able to study, we saw that the cancellous portion of the graft did not show anything like the amount of formation of new bone seen in cancellous portions of the iliac grafts (Figs. 2, 3, 4, 5, and 6). Cortical bone of the rib reacts more like that of cortical bone of the tibia, although it is less dense and is, therefore, more readily revascularized. Our observation indicated a better and quicker attachment to its host than in the case of the tibial bone. Moreover, in the split-rib graft, revascularization is much more rapid than in the whole-rib graft. The whole-rib graft may be pictured as a tube which is revascularized by vessels growing down through its long tubular canals from both ends. Little invasion of the graft, seems to occur at its cortical surfaces. Rapid revascularization of a rib graft occurs if it is

Series II

Our unsatisfactory experience with the use of the tibia in the first group of animals led to the selection of the foreleg in the second group. In the foreleg a segment of radius of approximately 1.5 centimeters was excised, creating in many instances a defect with non-union. The ulna was left as an intrinsic structure to prevent compounding. Non-union defects were created in the middle of the shaft of the radius on both sides. This site was chosen because, if the radius were excised near the wrist, radial deviation of the paw developed, which gave a poor and shortened graft bed. In some defects, a synosteosis formed between the fragments of the radius and the ulna. In others, the space between the two ends of the radius was filled with callus. Generally when a good synosteosis occurred between the fragments of the radius and the ulna, there was a better chance of maintaining the defect in the radius. In some cases, however, synosteosis developed, together with union of the fragments of the radius. The defects in the radius were allowed to remain from two to five months before bone-grafting was done. The grafts were obtained from the ribs, the tibia with periosteum, and the ilium. No fixation was employed other than a collodion dressing to the wound. In a few animals, the tibia which had been operated upon fractured where the cortical bone had been removed, but for the most part there were few complications. In one or two animals, a compound fracture of the ulna occurred and infection developed. We found that the radius was an excellent site for the production of non-union. In the grafting procedures, the tibial grafts were laid so that they bridged the defect entirely, with their ends inserted into the medullary cavities of the radial fragments. Iliac bone was similarly placed as far as possible, but often, when the defect was too long for bridging by a single piece of cancellous bone, it was necessary to overlap two pieces of ilium. The control series included animals with the preoperative defect, in which only freshening of the ends of the radius, and opening of the medullary canal had been done. The pairing of the experiment was as follows: (a) ribs against control, and (b) tibia against ilium. In this series of experiments, thirty-one animals were used from which originally sixty-four specimens were prepared. Of these sixty-four, thirty-four were finally obtained for study, from which there were:

Cancellous bone—11
Cortical bone with periosteum—8
Rib—6
Controls—7
Controls before second operation—2.

The conclusions reached in this series were the same as those attained after completion of the first series, with the exception of the whole-rib graft. Discussion of the relative value of full-thickness rib graft and split-rib graft is included in the discussion of Series IV.

Series III

In the third series of experiments, dogs were used. To ensure their good health and to acclimate them to their surroundings, the animals were kept for several weeks before operation. They were housed in wire cages in rooms at regulated temperature, and for a part of each day, they were allowed freedom of open runways. Their diet consisted of lung and hamburger, fortified with sardine oil for vitamin D and tomatoes for vitamin C. Anaesthesia was obtained with intravenous sodium pentobarbital, supplemented at times by novocain. The preoperative preparation consisted of clipping the hair with surgical clippers and thorough preparation with soap and water, alcohol, and merthiolate. Through a medial incision, the upper half of the tibia and the lower half of the femur were exposed. The patella and the cartilaginous surfaces of the femur and tibia were then excised, and a flap of bone was turned outward by incomplete vertical osteotomy of the tibial tubercle. Internal fixation of the femoral and tibial surfaces was secured by three Kirschner wires, and supplemented in our first group of experiments by plaster-of-Paris. Later the

FIG. 8

A: Appearance of graft in Fig. 7, two and one-half months after its removal and replacement.
B: Ten months after first operation.

margin, free cancellous bone. These margins lay free in the soft tissues between the first dorsal interosseus and the adductor pollicis brevis. They could, therefore, receive circulation only from the soft-part structures (Fig. 7, *A*). After a period of eighteen days, one end of the graft became loosened; and a second operation was necessary. At this time the graft was completely removed, its flanges trimmed for specimens, and again placed as a bridge between the metacarpal bones in exactly the same manner as in the first operation (Fig. 7, *B*). It was noted that the pattern of the cancellous bone left its imprint on the granulation tissue. Ten months after the first operation, the patient disliked the position and rigidity of the thumb and asked to have the graft removed (Fig. 8). Therefore, at a third operation, we were able to secure this entire graft to complete our study of cancellous and cortical bone in the same graft at periods of eighteen days and ten months, respectively.

In the eighteen-day specimen the cancellous portion of the graft showed fairly complete revascularization. The usual hyperaemic granulation tissue was growing throughout the medullary spaces, and the old trabeculae were surmounted by osteoblasts from which new trabeculae were growing (Fig. 9, *B*). In the cortical portion of the graft, revascularization was taking place in much the same fashion as in any graft of cortical bone. The major portion of cortical substance was dead, as shown by the absence of osteocytes in the lacunae. New vessels were growing into the old Haversian systems, and there was replacement with new bone (Fig. 9, *A*). In other words, in the two flanges of the graft where revascularization could only occur from the surrounding soft parts, the two types of reaction could be seen; in cancellous bone, early revascularization, and new-bone formation in abundance from the graft itself; in cortical bone, the slower revascularization with

first to the sixth lumbar vertebra were split longitudinally, and then pried apart to afford graft beds. Into the spinous process of the sixth lumbar vertebra, a piece of ilium with one cortical surface and one cancellous surface was inserted, so that the bone of the two types was applied to the cancellous surfaces of the spinous process. Into the spinous process of the fifth lumbar vertebra a wedge-shaped piece of the wing of the ilium, with one cortical surface intact, was put in an inverted position, so that its one cortical and two cancellous surfaces lay in contact with the cancellous surfaces of the spinous process. Into the spinous process of the fourth lumbar vertebra, a piece of tibial bone with its periosteum intact was placed, so that the periosteum faced outward. Into the spinous process of the third lumbar vertebra, a half section of rib with its cortical and cancellous surfaces was inserted. Into the spinous process of the second lumbar vertebra the spinous process of the seventh lumbar vertebra with one cortical surface removed was introduced. The split spinous process of the first lumbar vertebra was used as a control. Roentgenograms were taken of the six dogs immediately after autopsies had been performed.

The sites in the tibia where the bone had been removed for grafts were used as controls and for the study of cortical-bone chips placed in a bed of cortical bone. Fifty-four grafts were secured from six animals at intervals of five, ten, fifteen, twenty-one, forty-two, and sixty days. They were of the following types:

Cancellous bone—11
Cortical bone without periosteum—5
Cortical bone with periosteum—9
Spinous process—4
Rib—8
Rib defects—5
Controls—12.

Discussion: In this group of experiments, the same changes in cancellous and cortical grafts were noted as in the previous group. However, we were able to observe the changes of the split-rib graft used in this group of experiments, as compared with the second group of experiments in which were used the full-thickness rib graft and the spinous process, which is similar to the split-rib graft. In the split-rib graft, the medullary surface is rapidly invaded by vascular granulation tissue, which permits early formation of bone upon its old trabeculae. Furthermore, this rapid revascularization led to replacement by creeping substitution of the dead trabeculae, similar to that seen in cancellous-bone grafts. When the rib is intact, revascularization of the cortical bone takes place through the granulations which arise from the graft bed, and, even more so, from the granulation tissue downward into the medullary canal at both ends of the graft. The process here is similar to that seen in cortical bone of the tibia, although the cortex of the rib is less dense, and invasion and replacement are correspondingly rapid. Following this granulation tissue, there is formation of new bone, as described under the process of creeping substitution. Other details of the action of the rib graft are given later.

Series V

Seven dogs were used. Experiments were conducted to permit the study of grafts of cancellous bone placed in beds of cancellous bone. Through an anteromedial incision, a transverse osteotomy of the tibia was performed just below the tibial tubercle. The ends of the fragments of the tibia were separated by traction, and into the space created were placed wedges of cancellous bone from the ilium. Fixation was obtained by a Kirschner wire passed through the graft and the adjoining fragments of the tibia. The protruding end of the Kirschner wire was cut flush with the bone surface. In many of the experiments, roentgenograms showed this fixation to be inadequate, and in consequence there was displacement of the graft.

after periods of two and three years, respectively. In these specimens we found new trabeculae and some attempt at revascularization of the scar tissue, which had extended across the lines of non-union. In other words, in these two cases, there was an effort toward repair with the ingrowth of blood vessels in the laying down of some new bone. In another instance, a large iliac graft of pure cancellous bone was placed, which was removed approximately eight months after it had been inserted. Here, the graft showed collections of degenerated calcific debris, lying in the old intratrabecular spaces. The trabeculae were evidently dead with no attempt at revascularization. Grossly, this specimen was of a dry, pithy type, surrounded on one side by a heavy mass of callus, which seemed to overlap the central cancellous bone. This callus could be lifted off like a shell, although the shell had some vascular connection with the old dead cancellous portion of the graft.

The examination of the bone material taken at twenty-seven days from the site of a Hibbs bone-grafting operation, on a girl of twelve, showed many new trabeculae lying free in the growing granulation tissue. These new trabeculae seemed to rise directly from old trabeculae, although it was difficult to be certain, because of poor staining technique.

In the examination of the osteoperiosteal graft which had been placed in the spine, the only tissue which we secured was from the lamina. The changes here were very much the same as seen in the Hibbs operation, in that there were many new trabeculae forming from these freshly denuded laminal chips in their trabecular portions. In a tibial graft which had been inlaid in the split spinous process (Albee technique), the outer superficial portions of the graft showed empty lacunae and no evidence of revascularization, even after a period of sixteen years. Between the under surface of the graft and its bed of cancellous bone, there was good union, although fusion was incomplete at the upper portion.

In a sliding femoral graft of cortical bone, four months and four days old, there was ery poor revascularization and almost negligible replacement. Some replacement occurred long a few channels where the granulation tissue extended into the graft. In this case here were complicating factors, including a large hematoma.

SUMMARY

Our studies have permitted us to arrive at very definite conclusions with respect to he evaluation of cancellous and cortical bone when employed as graft material. At the ery outset, it should be said that in regard to the behavior of the fully matured bony lements, whether they be derived from cancellous or compact bone, there is no great ifference. The mature bony elements once transplanted do not, for the most part, survive. They constitute a mass which is so inert that it does not provide even a foreign-body reaction, and sooner or later will be replaced by that process known as creeping substitution. This process is exceedingly slow and extends over many months, with a gradually subsiding impetus. In any graft, whether it be of cancellous or cortical origin, the only elements which survive and which possess osteogenetic power in any degree, are the cells which form the so-called endosteal layer. This is also true, but to a lesser extent, of the elements of the cambium layer of the periosteum. Once these two fundamental features are appreciated, the relative merits of cancellous over cortical bone grafts become immediately apparent.

In the case of the cortical bone, the greater bulk of the graft is made up entirely of fully mature osseous elements. The endosteal layer is often absent or, when present, is exceedingly limited in amount. As for the most part the mature elements fail to survive, the graft itself exists, therefore, as an inert body which can only serve for a limited length of time as an internal splint. Before such a graft can be wholly replaced by living bone, its mass must be entirely removed. This can only occur by revascularization, the leaching out of the mineral elements, and autolysis of the collagenous scaffolding. Unfortunately, the very physical nature of cortical bone prohibits rapid substitution. The only pathways which a cortical graft presents for the ingress of new blood vessels are the small Haversian

forty days, except that there were more trabeculae, and they were of a denser character than those of normal iliac bone. Here the proliferating endosteal trabeculae united the graft to its bed. In one animal observed one year after operation, the site of osteotomy was defined only by a thickening of its endosteal surfaces, although in some sections there was also some periosteal thickening.

As stated before, roentgenograms were taken of all the specimens. It should be emphasized, however, that these are of less value for study of bone formation than information obtained by the microscope. The roentgenograms show an overlapping of the bone fragment which at times gives an appearance of union. They also show callus formation and the increased density of the graft bed at the margin of contact with the graft, indicating dead bone which has not been revascularized. Later they disclose a gradual merging of graft and graft bed with the intermingling of their trabecular patterns Our experience has been that the chief advantage of roentgenograms in experimentation has been the permanent record of the graft as to its position, its contact, and its relation to its host. Just as in clinical observations, they must be interpreted in correlation with the gross and the microscopic findings.

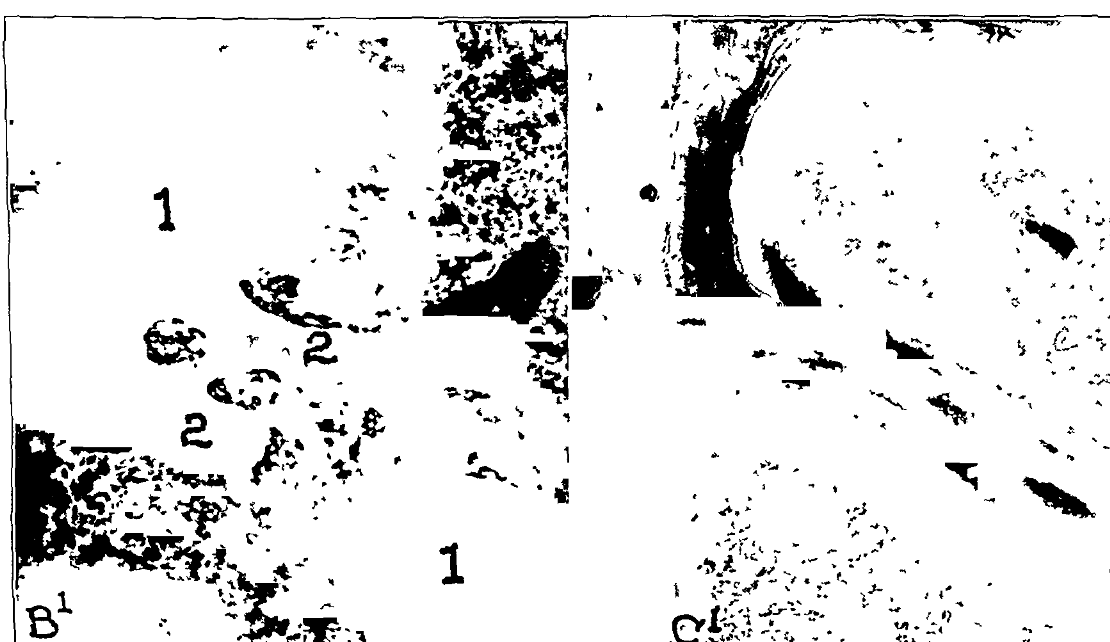


FIG. 3

High-power photomicrographs of sections shown in Fig 2.

A^1. Cortical bone at *1*; fibrin clot at *2*; no evidence of formation of new bone

B^1. Encircled portion of Fig 2, *B*, showing old trabeculae at *1*; cellular proliferation and new trabeculae at *2*.

C^1: Encircled section of Fig. 2, *C*. Note proliferation of cells on surfaces of trabeculae at *1*.

Non-Union, Either With or Without Loss of Substance

The condition of non-union with loss of substance is of common occurrence. In such cases the procedure is to freshen the ends of the fragments, and to apply single or multiple bone grafts to assure union. We believe the selection of the type of bone should be governed largely by the location of the fracture. If the fracture occurs at the end of the shaft of a long bone or in carpal or tarsal bones where cancellous bone is predominant, grafts of a cancellous-bone type should be used. Experimentally and clinically, these grafts rapidly become an intimate part of the surrounding bone, provided that fixation and accurate contact of the fragment are secured and maintained.

It is worthy of mention here that, as reported in an article by Dick, "Chips of cancellous bone from the ilium are now frequently used by plastic surgeons in reconstruction of the contour of facial bones, and these surgeons report that clinical rigidity of the reconstructed area is obtained in seven days". Iliac bone is also useful in repair of fractures of the jaw with loss of substance and in defects of the skull.

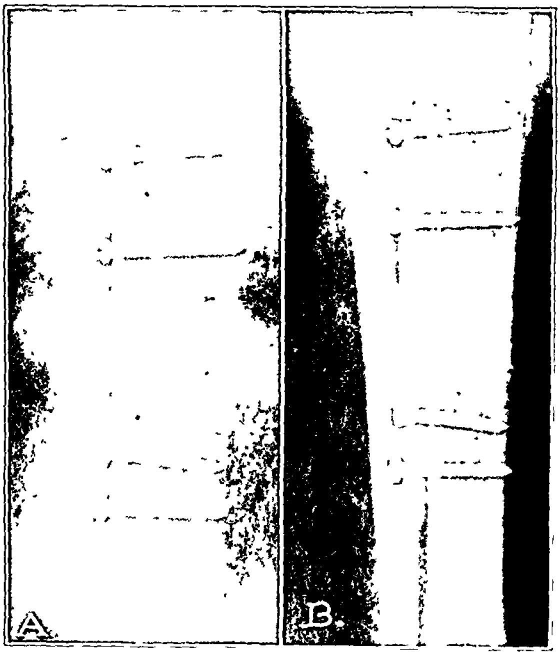
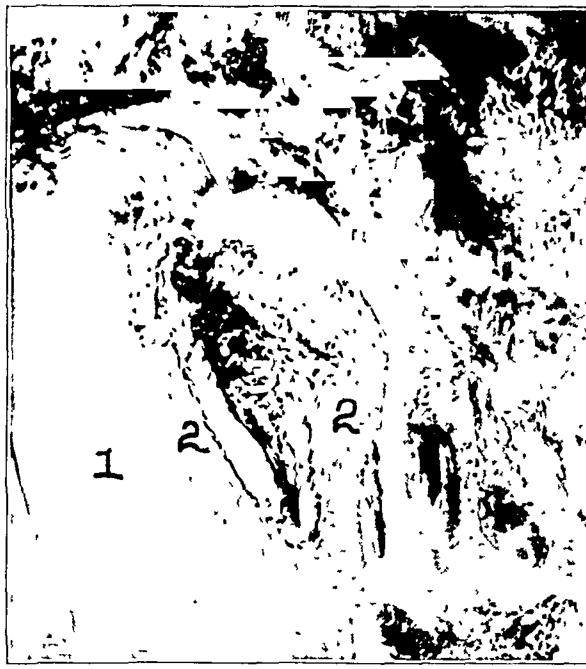


FIG 10

A Four days after application of an onlay graft for non-union of tibia in a patient fifty years of age.
B: Seven months after operation, showing bony union of graft and fragments.

In a fracture at the center of a long bone, where cortical bone is the predominant structure, and where strength is required throughout the period of revascularization and replacement, cortical grafts are preferable. They may be used as onlays (Campbell, Henderson), inlays, sliding grafts (Albee, Gill), intramedullary (Ryerson), the diamond-shaped graft (Gallie), the cortical periosteal splint graft (Phemister), the barrel stave (Steele), or the dual grafts (Boyd). The writers have a preference for the use of one or the other of the above types, depending upon the bone involved. For example, in the shafts of the humerus and femur, we prefer an onlay, fixed by stainless-steel screws, a method described by Key. In the shaft of the tibia we have used both onlay and inlay grafts (Figs. 10 and 11). In fractures of bones of the forearm and of the metacarpal and metatarsal bones, especially in fractures of the bones of the forearm with displacement and delayed union, intramedullary grafts applied after the method of Hoglund may be used. The technique of this method, as described by Phemister, consists in a graft cut from the cortex of the longer fragment, beginning one to two centimeters from the fracture and of a breadth that will fit snugly into the medullary cavity. It is introduced into the medullary cavity of that fragment at the fracture end. The fragments are then aligned and the bone graft driven outward by hammering on a chisel, placed at a right angle on its end through a window, approximately one-half of it resting in the medullary cavity of one end of the fragment and the other half in the other end. The collar of cortex left at the end of the fragment prevents the ends from being displaced. Cortical bone placed in cancellous bone takes a longer time to be revascularized and replaced and, in consequence, takes longer to become an intimate part of the surrounding cancellous structure. With the diamond-shaped graft of Gallie and the cortical splint graft of Phemister we have had no experience, but those surgeons who have used these methods report excellent results. The diamond-shaped graft is described by Gallie as particularly applicable to fractures of the radius and the ulna, while Phemister and Key

bone. The new trabeculae were characterized by light-staining tissue with plump, angular, and rather large osteocytes lying in fairly large lacunae. The graft bed at ten days showed similar changes with further increase in incrustation of the old trabeculae and formation of new trabeculae. The nuclei of the trabeculae were observed becoming more dense and staining more deeply. At sixteen days, the changes were progressive with increasing incrustation of old trabeculae, while the new trabeculae were much wider with several layers of cells. They were approximately double their original size. In the central portions of the large grafts, the trabeculae showed evidence of death by disappearance of cells in their lacunae. Our experimental evidence seems to indicate the necessity of revascularization of cancellous bone within the periods of ten and fifteen days, if it is to survive.



Specimens of iliac bone at twenty-one days showed the trabeculae to be very wide, with an increase in the number of new trabeculae (Fig. 4, *B*). In the grafts of forty-two days and sixty days, respectively (Figs. 5, *B* and 6, *B'*), the trabeculae seemed to approach their normal width and thickness, and restoration of the original pattern was gradually taking place. In some of our cancellous grafts in humans, which were subjected to stress and strain, changes occurred to a point where they might be taken for bone of a rather loose cortical type. In

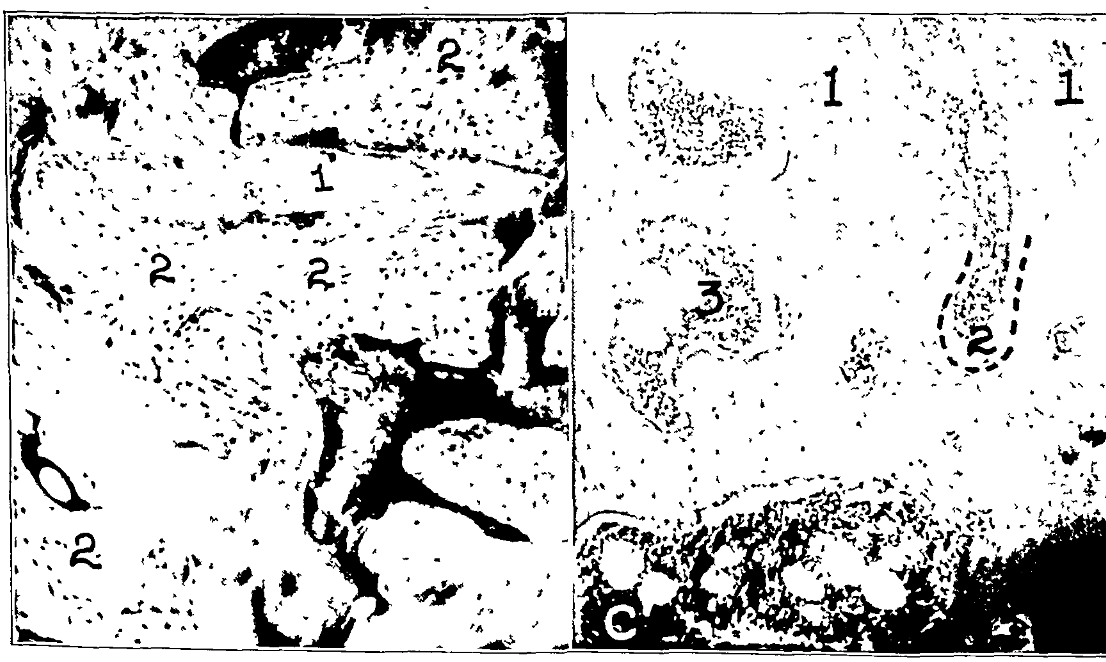


Fig. 6

High-power photomicrographs of sections shown in Fig. 5.

A': Cortical graft with dead cortical bone at *1*; new-bone formation at *2*.

B': Iliac graft, showing dead trabeculae at *1*, surrounded by active proliferation of new bone at *2*.

C': Rib graft, showing dead bone at *1*, new-bone formation at *2*, and vascular granulation tissue at *3*.

FIG. 13

A: Intramedullary fibular graft to ununited fracture of the humerus of six years' duration, with loss of substance, in a patient sixty years old.
B: Two months after operation. Arrow indicates absorption of graft and creation of defect.
C: Three months after operation, showing fracture of graft.

have reported success with the splint cortical graft in ununited fractures of the tibia. Phemister states that, in some cases of non-union of the tibia, infection may persist on one side of the bone only, and a whole-thickness graft may be inserted on the opposite side of the bone without entering the infected field.

We regard the osteoperiosteal graft as purely supplementary in character, while the barrel stave and double onlay grafts are particularly useful in non-union with loss of substance. It should be emphasized here that cancellous chips or strips can be used to advantage with cortical grafts to hasten union, especially when the ends of the fragments show marked sclerosis.

In bone-grafting in cases of non-union, the type of fixation requires special consideration. As is often the case, the ends of the fragments are surrounded by dense scar, and the extensive dissection required to free and realign the fragments deprives them of their blood supply. Consequently, they undergo aseptic necrosis with absorption of that portion of the fragments which has been deprived of this blood supply. Loss of continuity of bone is thus produced at the site of fracture, and maintenance of this defect by rigid internal fixation, especially by a bone plate, may be the cause of further delay in union or of persistent non-union. If fixation by plates is used, we believe supplementary grafts of cancellous bone from the ilium applied about the site of the fracture to be advantageous, as they revascularize rapidly and help bridge the defect caused by aseptic necrosis of the ends of the fragment. One of us (F. C. B.) has been so impressed with the frequency of the above-described condition, leading to delayed union or non-union, that he has relied on internal fixation of the graft by ligature, supplemented only by external fixation with plaster. In non-union of fractures of the tibia we have also tried a method in which a sliding graft is fixed at its upper end to the upper fragment by a single screw only, while at its lower end displacement of the graft is prevented by dovetailing its tip beneath the cortex of the lower fragment (Fig. 11). If aseptic necrosis occurs at the fracture site, resection of the fibula is done to allow obliteration of the gap and approximation of the ends of the fragments.

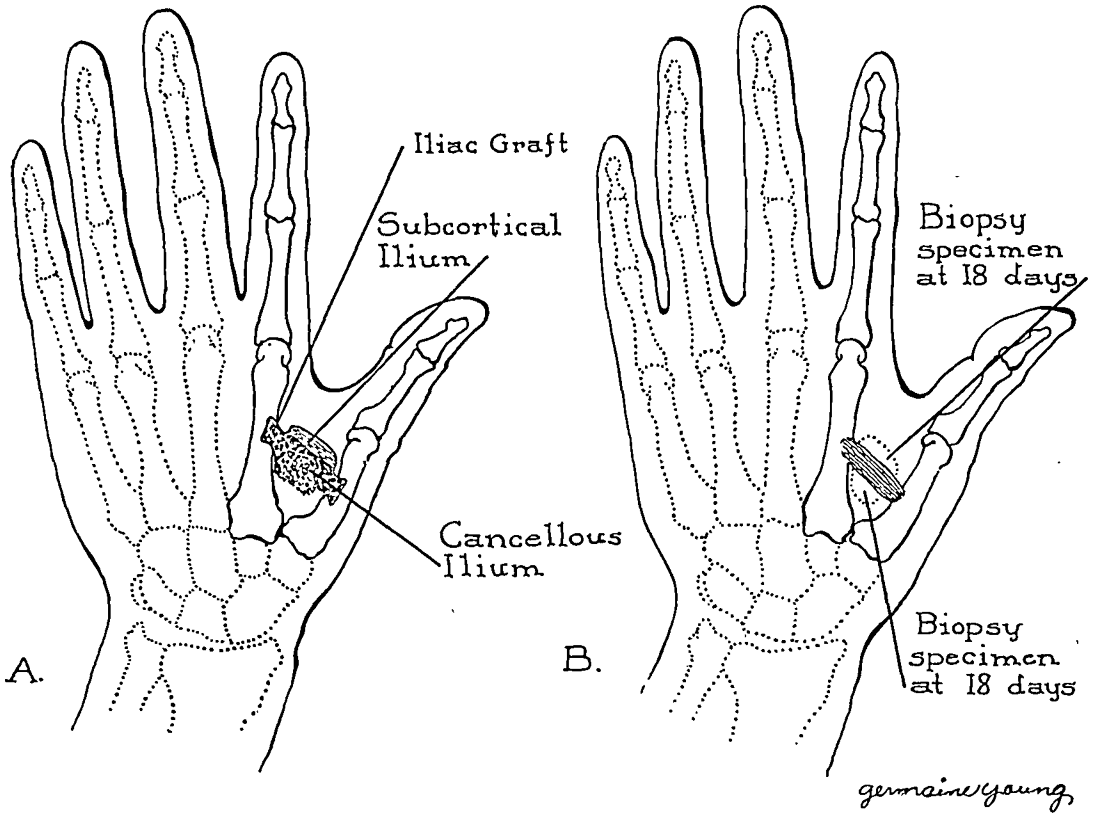


FIG. 7

A: Iliac graft in form of cross, placed between first and second metacarpal bones.
B: Graft removed and then replaced after specimen was taken for biopsy.

split to expose a medullary surface. It should be noted here that this difference between whole and split-rib grafts should be stressed. The cortical part of the graft showed some evidence of new-bone formation from its endosteum. Half of the split spinous-process grafts were similar to the split-rib grafts.

The cancellous-bone-graft bed exhibited the same changes seen in the cancellous graft, with rapid revascularization and evidence of new-bone formation at its margins.

HUMAN GRAFTS

In our study of the comparative values of cancellous and cortical bone grafts, we were able to examine grossly and microscopically specimens taken from eight iliac grafts, which were removed in part or whole at intervals varying from eleven days to three years. In addition, to complete our series, we also had three cortical grafts, an osteoperiosteal graft, and bone material obtained from the site of a Hibbs fusion of the spine and from a graft bed.

In the iliac grafts, the earliest one, an eleven-day specimen, showed no microscopic changes, except in a small area of revascularization where hyperaemic granulation tissue was growing into the medullary spaces. In this area, old trabeculae were lined by osteoblasts which were proliferating with new trabeculae growing out from them in much the same pattern of new-bone formation as seen in our experimental animals, where cancellous grafts of iliac bone were replaced in the ilium.

The best specimen that we have was secured in a girl of eighteen years with spastic hemiplegia. In this patient a graft from the ilium was placed between the first and second metacarpal bones to maintain opposition of the thumb. The graft was in the form of a symmetrical cross with two ends of one cross piece dovetailed into the shafts of the first and second metacarpal bones, respectively (Fig. 7). The ends of the other cross piece were trimmed, so that on one margin there was fairly dense subcortical bone and on the opposite

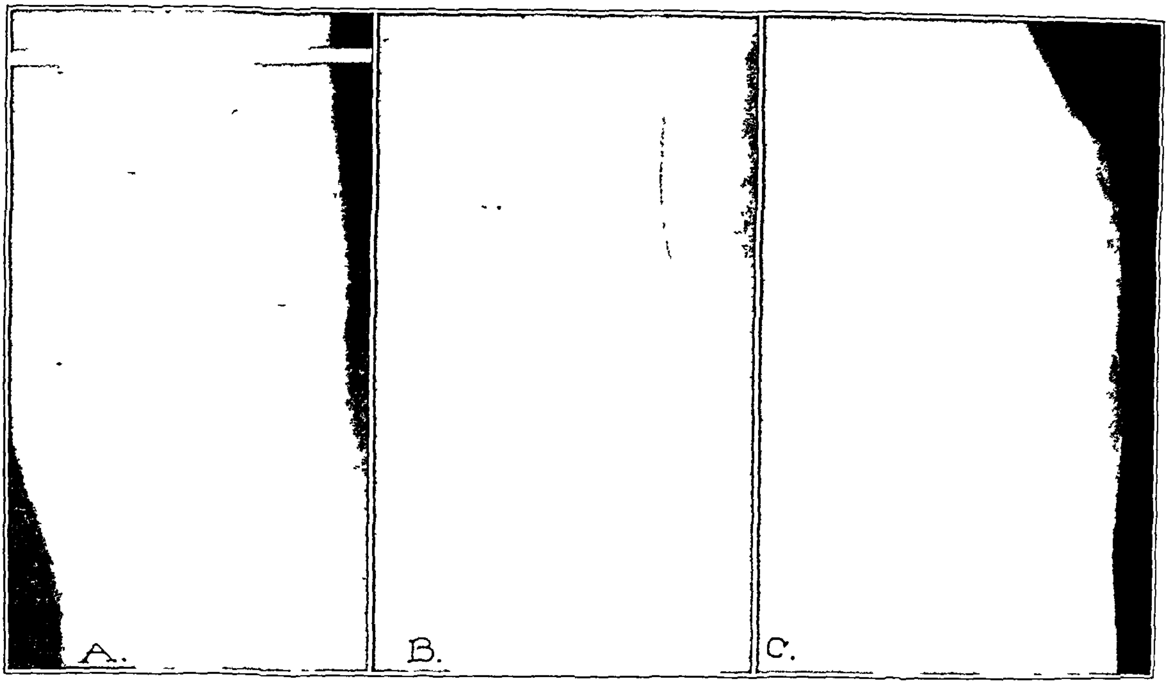


FIG 14

A Three months after excision from tuberculous knee and fixation by pins and turnbuckles (Key). Multiple iliac grafts were placed across the line of excision (Bost).
B and *C*. Bony ankylosis twenty-one months after operation.

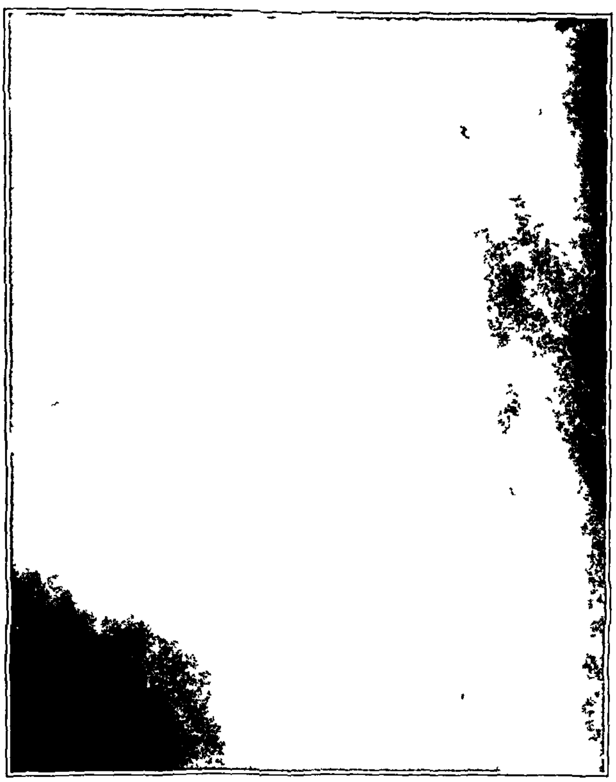


FIG 15

Full-thickness iliac graft placed between the ischium and the upper part of the femur for fusion of tuberculous hip (Bost).

below, the ends of which are fixed to an adjustable turnbuckle on both sides Supplementary grafts of cancellous bone from the ilium are wedged into vertical osteotomies which cross the line of excision on the anterior and lateral aspects of the joint (Fig. 14).

In fusion of the hip joint, we have used cancellous bone, packed around the surfaces of the joint; or we have employed full-thickness grafts of iliac bone, after the method described by Ghormley. Recently one of our group (F. C. B) has used a full-thickness iliac graft, wedged between the ischium and the inner surface of the upper femur (Fig 15).

Cancellous grafts have been used in fusion of the shoulder, elbow, ankle, and various joints of the hand and foot. The technical details vary with the needs of the individual case and, therefore, will not be described here However, we should like to point out the advantage of the temporary fixation, secured by Kirschner wires together with plaster-of-Paris, of the joints of the hand and foot to maintain accurate apposition of the bones and the graft.

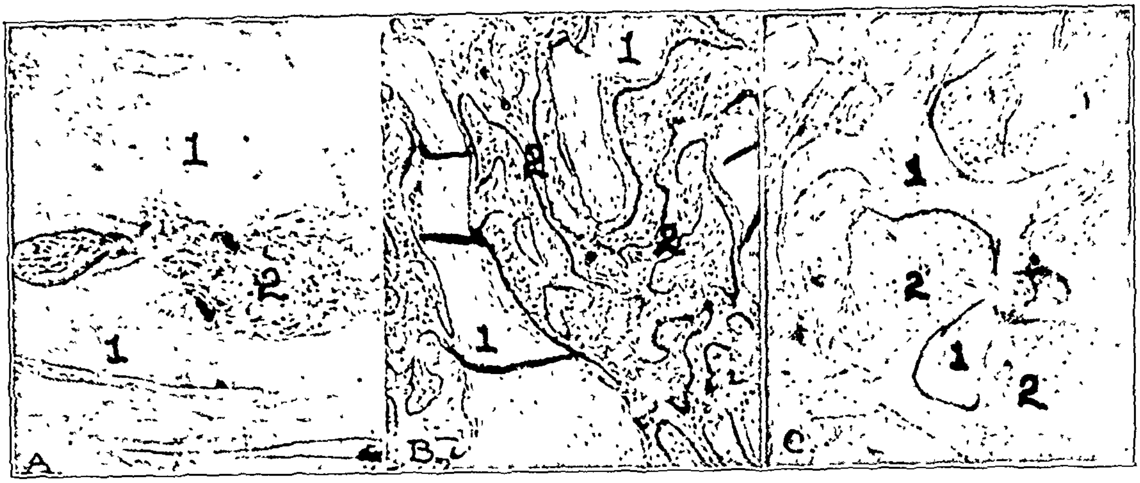


FIG. 9

Microscopic section of graft shown in Figs. 7 and 8.

A: Cortical portion of *graft at eighteen days, showing dead cortical bone at 1 and granulation tissue at 2,* illustrating the process of creeping substitution.

B: Cancellous *portion of iliac graft, showing old trabeculae at 1 and active new trabeculae at 2.*

C: Cancellous portion of graft at ten months. Old trabeculae at *1* surrounded by new bone at *2*.

subsequent replacement by new bone. These findings support those obtained in our experimental work with animals.

The study of this graft removed after ten months showed a heavy cortical margin with smooth outlines at the attachments to the two metacarpals. The graft showed an unbroken cortical border made up of new bone with old trabeculae showing here and there the original iliac pattern. These old trabeculae were *entirely surrounded by new bone* (Fig. 9, *C*). From the thin cortical margins of the graft, heavy trabeculae ran toward its interior. A large *number of these heavy trabeculae had as their centers the old primary* trabeculae which had not been replaced. A large number of the trabeculae in the interior of the graft still had osteoblasts lining them, and formation of new bone continued to occur from the greatly thickened trabeculae. The general shape of the graft remained the same as when it was laid. Within the central area of the graft, there was no longer a marked proliferation of granulation tissue. When it occurred, it was much thinned out, leaving an open network with fewer capillaries. It should be remembered that the circulation was disturbed by removing this graft eighteen days after it had been placed. This may account for the lack of complete replacement of the central portion of the graft.

In another full-thickness graft from the ilium with its cortical portion intact, removed eleven months after it had been inserted, a complete revascularization of the cancellous portions and a partial revascularization of the cortical portions were observed. Another iliac graft, also of the full-thickness type, removed eight months after it had been placed, showed new-bone formation in the cancellous portion, and the same type of replacement as seen in the cortical portion of other cortical-bone grafts, except that there was much heavier fibrous tissue with less vascularity in some of the deeper portions. In this latter graft there was an area of non-union at the site of a screw which had fixed it in place at the time of operation. This area consisted of fibrous tissue separating an active proliferating tissue from portions of dead tissue.

In a ten-month-old iliac graft of full thickness, an area of non-union developed, even after this length of time. The cortical sections of this graft were dead and showed incomplete replacement; and the majority of the lacunae were *empty*. *Some regions showed* revascularization, while the medullary portions of the graft had been replaced by fibrous tissue. There was *no evidence* of the formation of new trabeculae, and the area of non-union was marked by a very dense layer of connective tissue.

We have examined several other specimens of iliac bone in which non-union developed

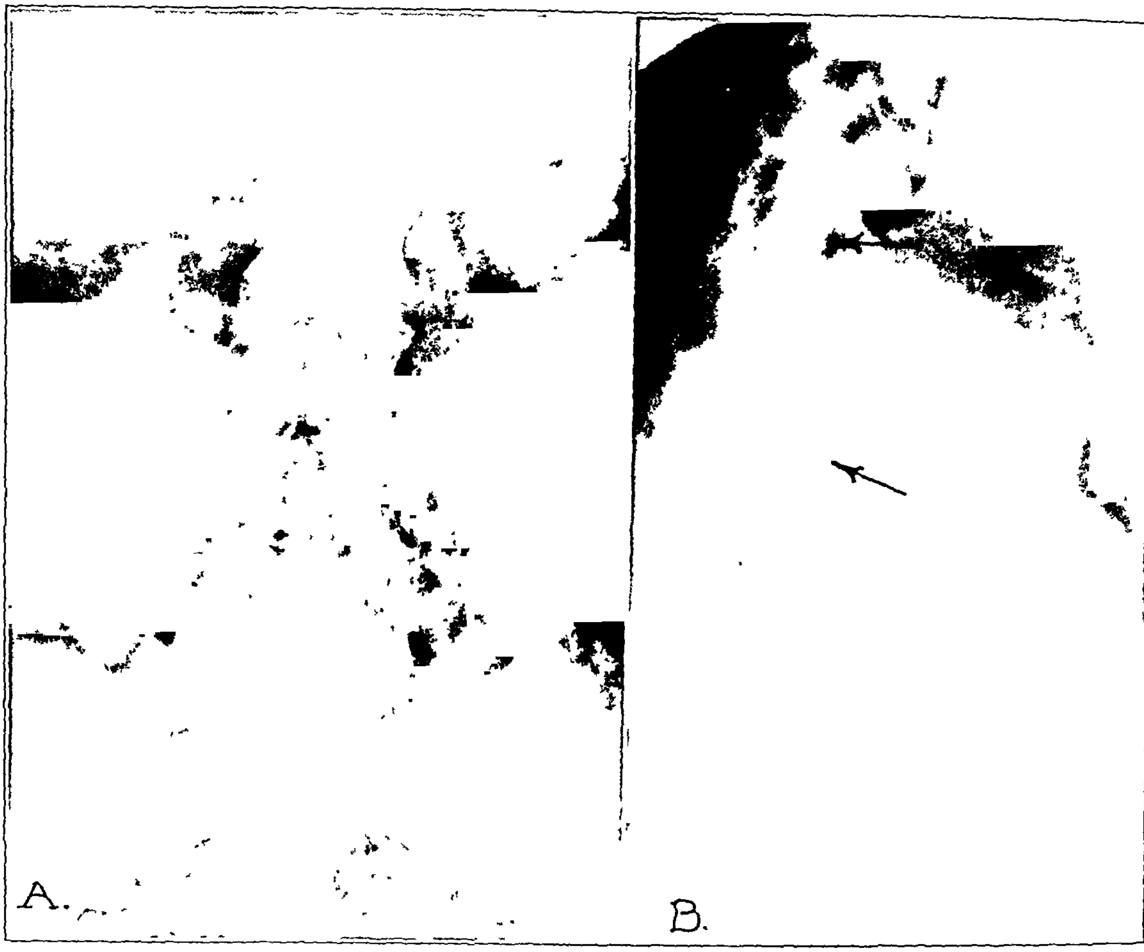


FIG. 18

A. Giant-cell tumor of transverse process of fourth lumbar vertebra after curettement, roentgenotherapy, and grafting with iliac bone.

B: Massive bone formation from iliac grafts shown at arrows. (Courtesy of Dr. Ernest Myers.)

and the spinous processes and laminae was without exception the best that occurred with any type of graft". Early and complete revascularization of the grafts takes place, and union is solid in an average time of three months. In fusion of the spine, we prefer to turn leaves of lamina outward on each side of the spinous processes, and place long struts of cancellous bone, taken from the posterior wing of the ilium, beneath these leaves in contact with cancellous-bone surfaces. Cartilage is removed from the facets, and these in turn are packed with cancellous bone. We have used cancellous bone in all parts of the spine, particularly in the cervical and lumbar regions (Figs. 16, 17, and 18). In lumbosacral fusion we have also used the method described by Breck and Basom, in which a bone graft, taken from the tibia or ilium, is placed between the notched spinous processes of the two vertebrae which are to be fused. In addition, we have curetted the facets, and driven wedges of iliac bone into them to produce greater fixation,—the so-called tripod fusion.

Correction of Deformities

Iliac bone in the form of wedges placed at the sites of osteotomies is employed to correct extreme deformities of the upper and lower extremities. This method, the details of which have been published elsewhere, allows for a gain of some length of the bone in cases of shortening. Cancellous bone has also been used in the form of wedge grafts where osteotomy has been performed through sclerotic bone. Although our experience with this method has not been extensive, evidence indicates that it will promote revascularization and the formation of new bone with earlier union than when two sclerotic surfaces are apposed. In such cases, drilling of the sclerotic fragments is also employed.

canals and the immediate surfaces in contact with the graft bed. Furthermore, since after the trauma of operation, the formation of new vessels reaches its critical point within a few days, and thereafter, with changes in biochemical conditions, starts to decline, the progress of penetration is choked off, and many regions of the graft remote from the vascular bed may never obtain a vascular supply. The cellular elements of the capillary tufts possess, as is well known, considerable potentiality in the direction of osteogenesis; but for osteogenesis to occur, an accommodation space must be available. Such space is not available in the case of cortical bone, until the original collagenous elements have been removed to provide for it. The graft, therefore, is in a sense a deterrent to the formation of new bone. New bone is laid down only on the surfaces of the graft, and, therefore, we frequently find cortical grafts becoming incorporated in, rather than replacing, new bone.

In the case of cancellous bone, conditions are far different. The mature elements of the trabeculae behave in much the same manner as that described for cortical bone, but each and every one of these trabeculae is provided with an endosteal surface possessing great osteogenetic power. In addition, there are the numerous marrow spaces. The bone-marrow cells themselves undergo rapid degeneration, and provide wide channels for the invasion of new vessels and eventually for the accommodation of newly formed bone. The cells of the endosteum rapidly come into relationship with a vascular bed, which accounts not only for their survival, but for the early proliferation and establishment of new bone. New trabeculae and the incorporation of the old is the characteristic picture in cancellous grafts. The old elements being small, and lying in such close relationship to vital elements, are removed and replaced more rapidly, although they, too, may remain for many months before complete substitution. In this connection, it should be pointed out that there is some difference between cancellous bone in which the marrow is highly fatty and that in which red marrow predominates. Fat has, as is well known, an inhibitory effect on the formation of new vascular tufts and where present to excess, the process of bone formation is retarded. This would account for the superiority of iliac bone, or bone obtained from other sources containing red marrow, over the fatty cancellous bone found, for example, in the lower end of the femur or the upper end of the tibia. In a word, then, the superiority of cancellous bone over cortical bone lies for the most part in the fact that the cancellous bone presents a very extensive endosteal surface and numerous accommodation spaces which allow for osteogenesis.

These distinctions are most exquisitely seen in the case of grafts derived from ribs where both elements — namely, compact and cancellous bone — are present. In such grafts there is the additional advantage that both processes may be observed in the same subject under identical conditions. The compact tissue of the rib differs slightly from that obtained from other sources, in that its Haversian spaces are more numerous and larger, thus allowing a more ready access to new vessels. The cancellous element is like that of other bones. In such grafts the observer is struck by the rapid formation of new osteogenic tissue about the trabeculated elements, in comparison to the slow and restricted process of creeping substitution occurring in the cortical portion.

CLINICAL OBSERVATIONS

Our clinical observations in operations for bone-grafting can best be described under the following headings: (a) bone-grafting in clean cases, and (b) bone-grafting in septic cases.

BONE-GRAFTING IN CLEAN CASES

The usual indications for the use of bone grafts in clean surgical cases are (1) non-union either with or without a loss of substance; (2) for fusion of joints; (3) for filling of defects in bone caused by trauma, infection, or tumor; (4) incomplete loss of substance in fractures; (5) for fusion of the spine; and (6) in correction of severe deformities of the extremities.

conveniently from the posterior portion of the iliac crest; if the patient is supine, the grafts are usually taken from the anterior part. To expose the anterior part of the iliac crest, an incision is made along the lateral margin of the crest of the ilium through the skin and subcutaneous tissue. The junction of the external oblique muscle above, and the tensor fasciae femoris and glutaeus medius muscles below, is recognizable as a white line where these muscles blend with the periosteum. A firm incision is made along this white line through the periosteum. This structure is then elevated medially and laterally, care being taken to stay as close to the bone as possible. Retraction of the muscles is facilitated by the use of two specially designed retractors with small sharp prongs which sink into the lateral surface of the ala. The bodies of the retractors can be levered upward and downward, pushing the muscles away from the crest and lateral surface of the ala. A wide surface of bone is then readily exposed.

In children, the technique for exposure of the iliac crest is somewhat different, so as to disturb as little as possible the epiphyseal cartilage which rims the crest. The incision through the periosteum is made along the lateral border of the crest. The glutaei are reflected laterally. The cartilaginous portion of the crest is incised along its junction with the bone, and raised upward and medially. By this method the cartilage is not separated from the muscles of the trunk, and the major part of the blood supply is preserved. When the cartilage is completely elevated, the upper part of the medial surface of the ala or iliac fossa is exposed. The grafts are removed with an osteotome, held either vertical to, or parallel with, the crest. In this way, grafts of various types can be obtained.

The method of repair after the removal of grafts is of great importance to the patient's postoperative comfort and early resumption of activity. The periosteal attachments of the muscles of the trunk and thigh are firmly sutured together over the iliac crest. We use interrupted figure-of-eight sutures of No. 1 braided silk. Walking is permitted six weeks after the full-thickness graft has been removed. In the cases in which small chip grafts have been removed, patients may walk without crutches in two weeks.

Other writers have described special techniques in removal of grafts from various parts of the ilium. Horwitz and Lambert have removed grafts of full thickness from the anterior crest of the ilium in lengths of from one to five inches. Rhinelander makes a special point of preservation of the inner cortex of the ilium. This point may be well taken, as evidenced by a complication recorded by Oldfield in which, after massive removal of the ilium, a sliding hernia of the caecum took place. Robertson and Barron turn the crest of the ilium upward; separate the two cortical surfaces of the bone, preserving the origin of the abdominal muscles; and then remove pure cancellous bone from its center (Fig. 19).

The complications following the removal of bone from the ilium can be obviated, if special attention is paid to the details of the technique of the procedure. Cancellous bone bleeds readily, and the formation of hematoma is common. In the majority of instances it can be prevented by the use of a synthetic preparation of fibrin foam or by the judicious use of bone wax. A second complication is the possibility that extensive stripping of the lateral surface of the ilium to obtain a wide exposure may cause weakening of the attachments of the glutaei, particularly the glutaeus medius and glutaeus minimus. This may produce the so-called "gluteal gait". In one patient, who had had a large cortical section removed from the lateral surface of the ilium to fill a defect in the skull, there was a rather serious and persistent limp, which lasted for six weeks. This condition can be avoided by accurate approximation and suture of the periosteal surfaces from which the abdominal and gluteal muscles arise.

The complications resulting from removal of bone from the tibia are fully appreciated by most surgeons. Fracture at the site of removal of the graft is not infrequent, and occurs as late as six months after the operation.

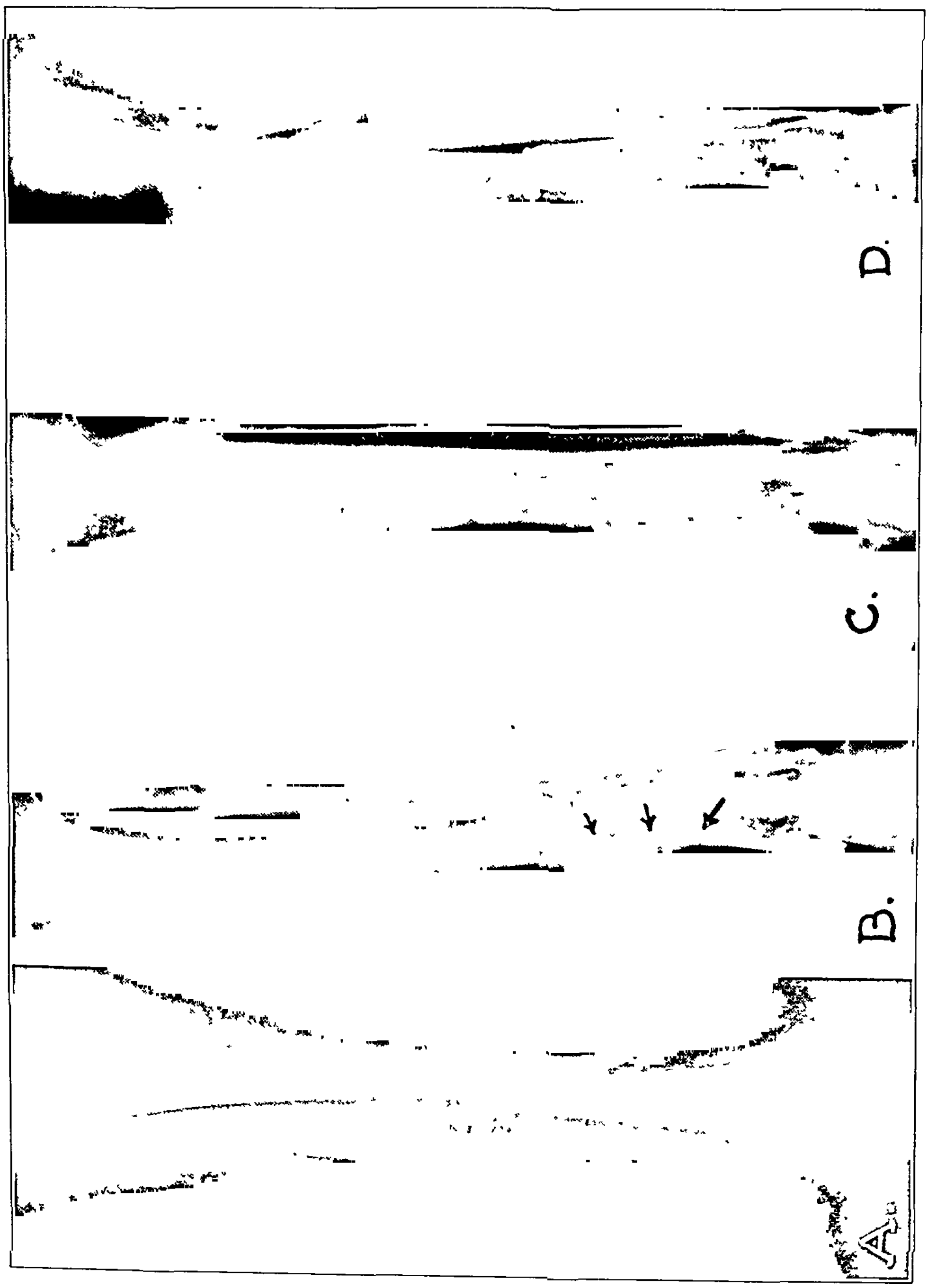


Fig. 11

A: Spiral fractures of tibia and fibula with non-union of both bones eight months after injury.
B: Sliding graft with lower screw fixing graft to upper fragment only; lower end dovetailed beneath cortex of lower fragment. This method allows fragments to telescope one another in cases of aseptic necrosis of the ends of the fragments.
C and *D*: Bony union five and one-half months after operation.

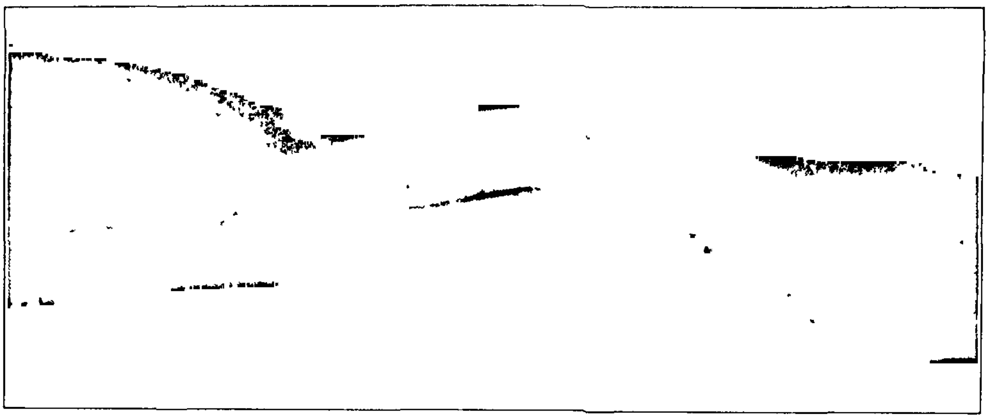


Fig. 12

Rib graft placed in large defect of radius in 1919. Appearance of graft twenty-seven years later, showing restoration of defect.

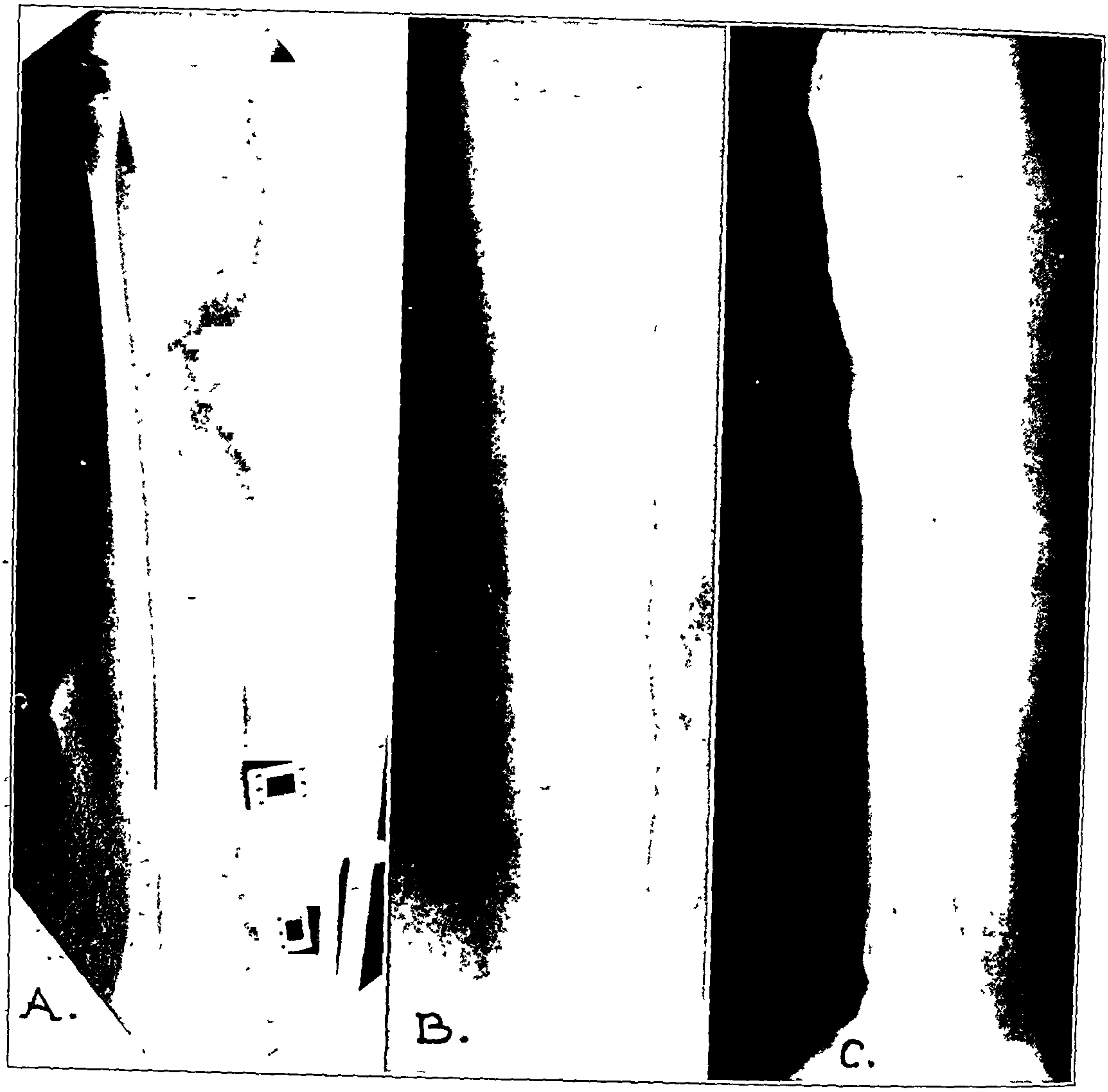


Fig. 20

A: In 1943 a large segment of the tibia was resected for chronic osteomyelitis.

B and *C*. Iliac bone was placed in the defect on Feb. 29, 1944, and on Nov. 4, 1944, in the presence of a granulating wound. Upper and lower ends of the fibula were transplanted on Sept. 15, 1945, and Nov. 26, 1945, respectively. Roentgenograms were taken in May 1946.

"2. Packing of complete defects of bone with cancellous bone and internal fixation by a plate is unsuccessful as the iliac bone absorbs without the stress of an impacting force, and the plate holds the bones apart."

In other Centers, defects both at the center and ends of the shafts of the long bones were filled entirely with cancellous bone. In one Center in particular, Colonel Ernest Myers and his associates had a large group of cases in which defects had been obliterated completely by this method. These cases were observed at periods up to six months after operation. Nearly all of them showed a homogeneous type of bone filling the defects and uniting the fragments, with no differentiation, however, into the cortical layers and medullary canal.

At Letterman General Hospital, we have observed a group of these patients whose defects have been filled by cortical bone, cancellous bone, or a combination of the two types, after varying intervals of six months to a year after operation. In some, success has been attained; in others, the defects have been healed and the fragments united, but refracture has occurred through immature and unorganized bone. A year after the end of the War we were seeing a comparatively small group of cases which presented difficult problems. In the majority of them, failure of union or the occurrence of refracture indicated that another operation was needed.

In fractures with loss of substance, we encounter a problem, the solution of which is accomplished with great difficulty. The many instances in this War of failure of bone-grafting in the presence of gross defects of bone stress the need of further study of these cases. As so many of these are compound fractures with infection, we prefer to discuss them under the section dealing with bone-grafting in the presence of sepsis.

In fractures of the bones of the upper extremity with gross defects, segments from a rib may be employed successfully. We have one case, a fracture of the lower part of the radius, operated upon in 1919 by Eloesser. Figure 12 shows the repair after twenty-seven years. At the present time function of the extremity is good. Eloesser reported twenty-two cases of non-union and defects, repaired by rib grafts. In seven cases, fracture of the graft occurred. Most of the fractures in the graft united.

In fractures of the long bones of both the upper and the lower extremities, segments of the fibula may be used to fill the defect. In many instances the bone does not become hypertrophied sufficiently to stand great strain and may fracture (Fig. 13). In fractures of the tibia with defects, the ends of the fibula may be transferred and grafted to the fragment of the tibia. In children, the fibula will become hypertrophied and attain the size of the tibia in several years. If hypertrophy of sufficient amount to withstand the strain of weight-bearing is not anticipated in an adult, sufficient bone-grafting of some type to join the fragments of the tibia is generally advisable.

Fusion of Joints

Fusion of the joints of the extremities is a procedure frequently employed by orthopaedic surgeons to restore function, when their cartilaginous surfaces have been extensively destroyed by injury or disease. Ankylosis may be secured by erasure of the cartilage or by excision followed by adequate fixation. However, in many cases, bone-grafting is essential to early and complete union. Many surgeons still employ cortical-bone grafts owing largely, we believe, to a lack of appreciation of the merits of cancellous bone. After an experience of many years in performing fusion of the major joints of the extremities, we wish to emphasize the great advantages of cancellous bone. Our experimental and clinical observations show that a cancellous-bone graft, placed in a bed of cancellous bone, is revascularized and becomes a part of the host far more rapidly than does cortical bone so used. Furthermore, cancellous bone can be used in the form of chips to fill interstices, created by removal of cartilage as, for example, in the bones of the wrist, hand, and foot, thus decreasing the time required for fusion. Moreover, it is pliable and can be readily molded to the external aspect of the joint. Its application, therefore, does not require the expert carpentry needed with the use of cortical bone.

Although we shall not discuss in detail our methods of fusions of joints, we should like to refer to some points in the technique which are considered of value in fusions of the wrist, the hip, and the knee. Our technique of wrist fusion has been described elsewhere. We wish, however, to emphasize the importance of preservation of the inferior radio-ulnar and carpometacarpal joints to ensure maximum function of the hand.

In publications on the use of cortical bone for fusion of the wrist joint, illustrations show the struts of bone dovetailed into the lower end of the radius, and the base of the second and third metacarpals. This results in a rigid wrist, which is a needless and severe handicap. In all cases, the carpometacarpal joints should be preserved, except where these joints have been seriously involved by injury or disease. The motion in these joints will gradually increase with use, and in addition a resiliency is provided which acts as a shock absorber to counteract the effects of a blow or a fall on the hand. With the preservation of motion in the inferior radio-ulnar and metacarpal joints, fusion of the radiocarpal and intercarpal joints no longer causes serious disability.

In excision of the knee joint we follow the technique employed by Key, with removal of the surfaces of the joint and fixation of these surfaces under pressure by pins above and

be reserved for the individual case presenting a difficult problem, and should be done only by an experienced surgeon. It is of interest that the massive sliding graft was used successfully by Gill in fractures of the forearm.

Rhinelander used strips of cortical cancellous bone from the ilium in bridging defects of the long bones. He emphasized the importance of dovetailing these strips into the ends of the fragments, and, in addition, the placing of strips of bone about the periphery of the defect so that they overlap the ends of the fragments. Complete filling of spaces between strips of the graft is secured by cancellous-bone chips. Rhinelander has also used this method in combination with a cortical onlay graft, fixed by metal screws or with a metal plate above. Dick has used dual grafts and cancellous chips successfully in massive defects of the tibia. Boyd has reported twenty-four cases, in twenty-two of which dual grafts were used successfully. He has emphasized their importance in securing fixation of fractures near joints. In such cases of ununited fractures near joints, Key has employed his dual plate successfully. In our experience in compound infected fractures of the tibia with defects, or after resection of segments of the tibia for osteomyelitis, we have used cancellous bone to bridge the defect, and then transferred the ends of the fibula to the tibia for its supporting effect (Fig. 20). In other cases, one of us (F. C. B.) has used a cancellous-bone bridge to unite the upper and lower ends of the tibia and fibula. Cancellous bone has also been used to bridge the gap after resection of the radius for osteomyelitis (Fig. 21).

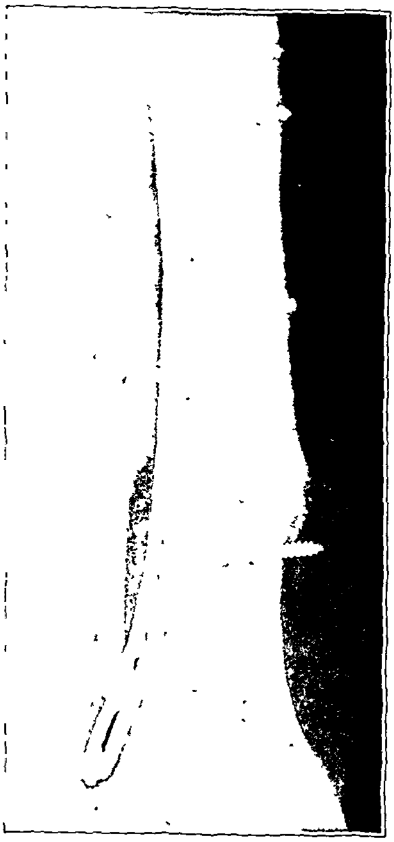


FIG 22

Roentgenogram taken two years after defect had been filled with cancellous bone, in a case of compound fractures of tibia and fibula, shows restoration of the medullary canal.

After a careful consideration of our experience, we are impressed by the fact that, in attempts to bridge defects with bone grafts, union of the ends of the fragments and the ends of the graft occurs with regularity, no matter what type of graft is used, provided, of course, that there is sufficient contact, overlap, and fixation. It would appear, therefore, that in the average case, the normal physiological process of revascularization and the formation of new bone from the osteogenic tissues at the ends of the fragments and the graft result in union of the ends of the graft to the ends of the fragments. In addition, the growth of new bone may close the defect, if it is not too extensive. If it is too extensive, the normal physiological process is interrupted, perhaps by a chemical change and an ingrowth of scar tissue from the periphery. Therefore, it may well be that, in a large defect, a single operation will not be sufficient because, with the gradual shutting off of the circulation and growth of scar, there seems to be a limit to the degree of bone repair and, therefore, a limit to the degree of bridging of a gap that may be anticipated. At present we are of the opinion that large defects in the long bones which have to withstand the strain of weight-bearing can be treated by a combination of cancellous and cortical grafts at a single stage or probably best by a two-stage operation. We are referring now only to those cases with large defects, where the physiological process is impeded and repair is incomplete. This failure of repair commonly occurs at the center of the defect. Furthermore, we have ample clinical evidence to prove that union of fragments can be effected across a gap by filling the interval with cancellous bone. This bone is of a homogeneous type, and its differentiation into the cortex and medulla requires a long period of time. This differentiation is the best assurance for the prevention of refracture. That this remolding with restoration of the normal texture will occur has been demonstrated in our cases. In one patient, fifty-seven

FIG. 16

FIG. 17

Fig. 16: Fusion of spinous processes and occiput, secured by iliac grafts in a case of ununited fracture of odontoid of six years' duration.

Fig. 17: Tuberculosis of the thoracolumbar spine. Cortical graft applied in 1938, cancellous grafts from ilium applied to lumbar spine in 1943, joining cortical graft at thoracolumbar region. The relative amounts of bone produced from cortical and cancellous bone grafts are shown on roentgenograms taken in 1946. Dotted arrows indicate the cortical graft, and solid arrows indicate the cancellous grafts.

Defects in Bone Caused by Trauma, Infections, and Tumors

Our experience in dealing with defects produced by one of the above causes has been largely in cases where cysts or giant-cell tumors have created cavities in the ends of the long bones. Here again we adhere to the principle of filling a cancellous-bone cavity with the same substance. If struts of cortical bone are laid across a large bone cavity, they may unite; but we have found that the spaces between them are not filled and, therefore, the cavity is not entirely obliterated. On the other hand, a cancellous-bone cavity packed completely with cancellous bone will heal with complete obliteration of the cavity. We have also found cancellous bone to be useful in cavities occurring in bones of the carpus and tarsus and in non-union of these bones. Furthermore, we have used it successfully in fractures of the shafts of the metacarpal and metatarsal bones with loss of substance.

Loss of Substance

In fractures with partial loss of substance, healing may be very slow, union is often weak, and refracture may occur. In clean cases, cancellous and cortical bone can be used if the defect is in the central portion of the shaft; if the defect is in the cancellous portion, cancellous grafts are preferable. In the presence of sepsis or where there is danger of the lighting up of a latent infection, cancellous bone only should be used.

Fusion of the Spine

Ghormley and Stuck, from their experimental work, have stated that, in fusion of the spine with cancellous-bone grafts taken from the ilium, "The union between these grafts

FIG. 24

A: Old compound fracture of tibia and fibula with infection, draining wound, and loss of substance. Outline of iliac graft four months after placement.
B: Fracture of iliac graft five months after placement.
C: Union of fracture and fractured graft seven months after transplantation of both ends of fibula.
D and *E*: Patient fractured his grafted area a second time, and another massive iliac graft was placed posteriorly, bridging the fracture sites of both tibia and fibula. Roentgenograms taken nine months later, showing union of graft and fracture.

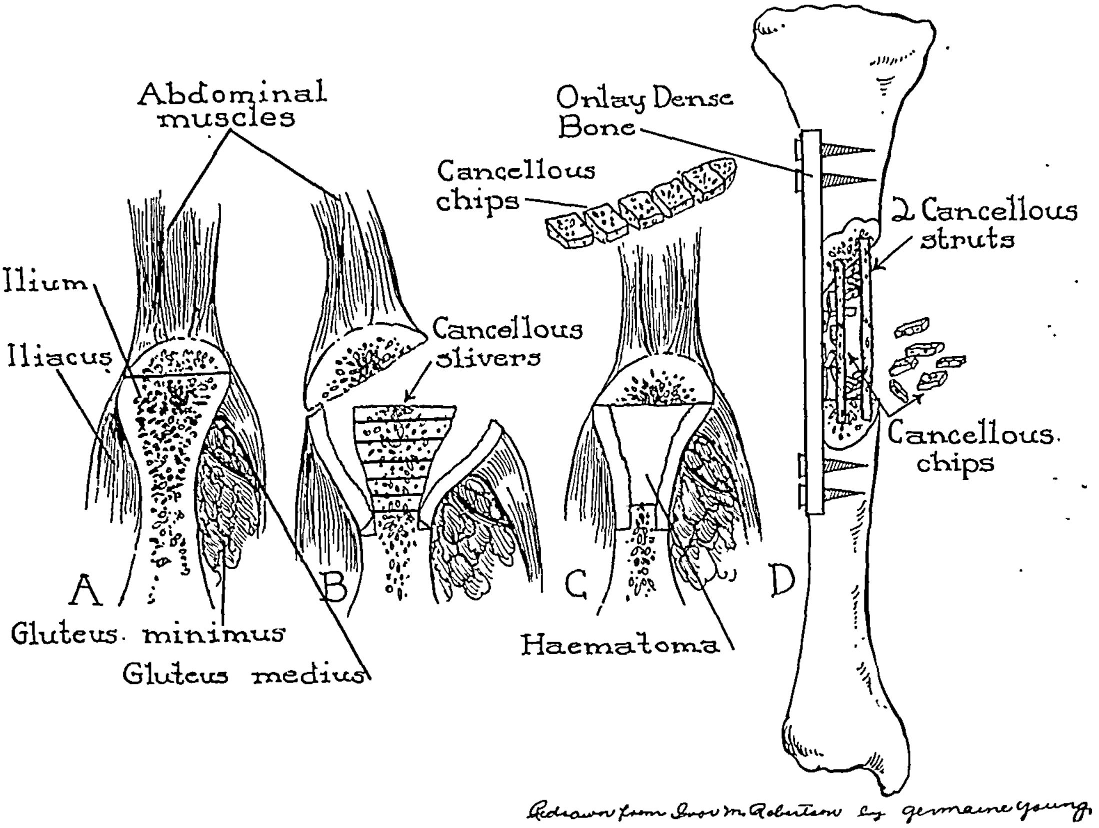


FIG. 19

A, *B*, and *C*: Diagram of method of removal of cancellous bone from ilium.
C and *D*: Diagram of placing and fixing onlay cortical graft and the use of cancellous chips. (After Robertson and Barron.)

It should be emphasized here that, no matter what type of bone is used in the treatment of delayed union, non-union, or bridging of defects, the bone grafts should be onlaid, inlaid, or dovetailed into the ends of the fragments to permit overlapping of the graft and the fragment, fixation, and consequent early revascularization.

THE ANATOMY OF AND THE SURGICAL APPROACH TO THE ILIUM

The ilium forms the upper part of the innominate bone. It consists of a body and an upper portion or ala. In our description, we are concerned only with the ala. The superior margin of the ala, which is roughened and thickened, is known as the iliac crest. Upon this crest are three rough lines, produced by the attachment of the abdominal muscles. The crest is subcutaneous throughout its entire extent, and is covered by a thick layer of periosteum.

The iliac crest is composed of three distinct curves which divide it into three sections, the posterior section being the longest. The convexity is medial in the anterior and posterior thirds, and lateral in the medial third. The ala is composed of thin inner and outer layers of cortical bone, which enclose a central portion of cancellous bone. With the exception of the posterior third of the bone, the iliac crest is the widest part of the ala of the ilium. When the ilium is cut in coronal sections, the anterior third is approximately one-half inch in thickness. The widest portion is at the junction of the anterior and middle thirds, the narrowest portion being at the junction of the middle and posterior thirds. In this region, it is composed only of the inner and outer layers of cortical bone, without a central portion of cancellous bone. The posterior third of the crest is the thickest part of the bone. This thickness is increased as far as the level of the sacro-iliac joint.

Bone grafts may be taken from any portion of the iliac crest, depending upon the type, size, and shape of the graft desired. If the patient is prone, grafts are removed most

and postoperative use of penicillin. Considerable success has attended this method of treatment in cavities occurring in the ends of the bones, particularly in some of the cases of chronic infected cavities of the calcaneus. Starr has used cancellous bone to fill these cavities, together with primary closure of wounds by plastic procedures. Successful closure, without breaking down of the wound after the operation, has been secured in a high proportion of cases. It is essential, as emphasized by Rhinelander and Starr, that cancellous bone only be used. Cortical-bone chips sequestrate with uniformity. These surgeons have kindly permitted us to refer to their work in this article.

In our own work at the University of California Hospital and affiliated hospitals, we have had a series of fifteen cases of infected compound fracture and one case of tuberculosis of the knee of many years' duration with formation of secondary infection and a sinus. The joint was excised, and the cavities in the lower end of the femur and upper end of the tibia were filled with iliac bone. The wound was closed, with a tube inserted for topical administration of penicillin for a period of ten days. This drug was also given intramuscularly for three months after the operation. Primary healing of the wound was secured with solid ankylosis of the joint in six months (Fig. 25). In this case, the pathological examination showed tuberculosis, secondary infection, and xanthomatosis.

Our conclusions were that, in compound fractures with infection, chances of securing primary healing were enhanced by thorough surgical removal of infected tissues and non-viable bone, in conjunction with adequate penicillin therapy. In most instances, it is advisable to attempt to obtain complete healing of the bone and soft tissues before undertaking bone-grafting. The use of metal plates for internal fixation should be avoided if possible. If such plates are indispensable, they should be removed at an early and suitable time. It is important to avoid tension in closure of the soft tissues. In certain cases, where closure can be effected only with difficulty and the wound must remain open, a complete packing of the wound with bone of the cancellous type is justifiable. This is a procedure articularly applicable where large cavities have occurred at the ends of the long bones, such as the lower end of the femur and upper end of the tibia, or in extensive septic cavities in the tarsal bones, especially the calcaneus. In such cases, particularly the tarsal bones, the soft-part tissues will heal slowly after the graft has taken, and healing will be facilitated by split-thickness grafts and later some plastic procedures to get full-thickness skin pliable and movable over the surface of the cavity.

SUMMARY AND CONCLUSIONS

In conclusion we should emphasize that the mature elements of either a cortical or a cancellous-bone graft seldom survive transplantation. Those elements which may survive and produce new bone are the cells of the so-called endosteal and periosteal layers. A cortical graft is a solid mass of mature elements with its surfaces covered by endosteum and periosteum. Therefore, it possesses strength, but has little osteogenetic power. On the contrary, cancellous bone is of a loose pattern, with interlacing and branching trabeculae, every one of which is covered by endosteal cells. It possesses a high osteogenetic power. Furthermore, this very loose structure permits of early and thorough revascularization. Cortical bone as a grafting material is most useful where strength is of primary importance, as in the ununited fractures of the shafts of the long bones. It may be used to advantage with cancellous bone which furnishes the osteogenetic medium. Cancellous bone as a grafting substance is preferable in the treatment of ununited fractures of the ends of the long bones and defects of bone caused by tumors or infection, for fusion of joints, fusion of the spine, and in correction of severe deformity by the open-wedge type of osteotomy.

In compound fractures with infection, early and complete healing of the wound by excision of scar, removal of sequestra, plastic procedures on the skin and soft parts, and by the use of the sulfonamides and penicillin, is of the utmost importance. Compound infected

BONE-GRAFTING IN SEPTIC CASES

Bone-grafting in the presence of infected bone has generally been regarded by experienced surgeons as a hazardous undertaking. In World War I, such procedures were commonly followed by a lighting up of the infection with its serious consequences, including loss of the graft by sequestration. Therefore, it was a common practice to postpone operations for bone-grafting in infected compound fractures for at least a year after the wound had healed. Even then, certain precautionary measures were often adopted, such as excision of scar tissue, manipulation, and deep massage, in an effort to stir up latent infection in the tissues. If this occurred, a further postponement of the operation was indicated. Some surgeons excised the scar tissue in the soft parts, prepared the bed for the graft, and then closed the wound without actually placing the graft. If this did not cause a flare-up of infection, a second operation was performed to place the graft. It is true that a large proportion of these grafts were taken from the tibia, although Eloesser pointed out that rib grafts, in whole or in part, withstood infection better than cortical bone. At that time, the viability of cancellous bone in the presence of infection was not generally appreciated. In World War II, many compound fractures healed without infection because of the thorough excision of the wound, early secondary closure, and the use of penicillin and the sulfonamides. Furthermore, experience has shown that, where infection of the bone has occurred, the operation, including bone-grafting, can be performed earlier, if infection is controlled by the judicious use of penicillin before and after the operation. An excellent article on the use of various types of bone grafts in the treatment of infected compound fractures has been published by Moore.

In this group of infected compound fractures, there are many cases of non-union without loss of bone substance. The cases without defects may be treated in much the same manner as described in the section on Bone-Grafting in Clean Cases.

During the recent War, one of us (L. C. A.), in his capacity of Civilian Consultant in Orthopaedic Surgery to the Secretary of War for the Ninth Service Command, was privileged to witness the methods employed by a number of excellent orthopaedic surgeons in the treatment of major defects in bone in compound infected fractures. All of these surgeons agreed on the advisability of obtaining a healed wound by removal of infected scar tissue and sequestra and the use of plastic procedures, before resorting to the operation of bone-grafting. They also agreed that so far no surgeon had the final answers to the best method of bone-grafting a defect in bone. In one Center, a group of cases was reviewed which had been operated upon by Colonel Carl Horn and his assistants. Major defects, after resection of segments of the shafts of the long bones for the eradication of infection, were filled by cortical grafts, two or three in number, obtained from the tibia and fibula. Particularly in defects of the femur, triple grafts were used,—one obtained from the tibia, the other two by inserting a long segment of the fibula. These grafts were fixed to the fragments by screws, while the span between the grafts was filled by cancellous bone from the ilium. Too short a time has elapsed to permit an evaluation of the end results in these cases, but in reply to a recent inquiry Colonel Horn states, "some general statements that appear justified at this time are:

"1. In complete defects of bone, where shortening is not desirable, the use of dual cortical grafts or triple cortical grafts (one tibial and two longitudinally split fibular grafts) combined with cancellous bone has given the best results. For example, (a) one patient with a three-inch defect of the femur treated with dual cortical tibial grafts and cancellous bone had clinical and roentgenographic evidence of union at five months; (b) one patient with a seven-inch defect of the femur treated by triple cortical and cancellous grafts had complete incorporation of the grafts at seven months, but he fractured the graft at a mechanically weak spot on exercise. The fracture is realigned perfectly, but it will probably need some more cancellous bone to hasten recovery.

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Our conclusions were that, in compound fractures with infection, chances of securing primary healing were enhanced by thorough surgical removal of infected tissues and non-viable bone, in conjunction with adequate penicillin therapy. In most instances, it is advisable to attempt to obtain complete healing of the bone and soft tissues before undertaking bone-grafting. The use of metal plates for internal fixation should be avoided if possible. If such plates are indispensable, they should be removed at an early and suitable time. It is important to avoid tension in closure of the soft tissues. In certain cases, where closure can be effected only with difficulty and the wound must remain open, a complete packing of the wound with bone of the cancellous type is justifiable. This is a procedure particularly applicable where large cavities have occurred at the ends of the long bones, such as the lower end of the femur and upper end of the tibia, or in extensive septic cavities in the tarsal bones, especially the calcaneus. In such cases, particularly the tarsal bones, the soft-part tissues will heal slowly after the graft has taken, and healing will be facilitated by split-thickness grafts and later some plastic procedures to get full-thickness skin pliable and movable over the surface of the cavity.

SUMMARY AND CONCLUSIONS

In conclusion we should emphasize that the mature elements of either a cortical or a cancellous-bone graft seldom survive transplantation. Those elements which may survive and produce new bone are the cells of the so-called endosteal and periosteal layers. A cortical graft is a solid mass of mature elements with its surfaces covered by endosteum and periosteum. Therefore, it possesses strength, but has little osteogenetic power. On the contrary, cancellous bone is of a loose pattern, with interlacing and branching trabeculae, every one of which is covered by endosteal cells. It possesses a high osteogenetic power. Furthermore, this very loose structure permits of early and thorough revascularization. Cortical bone as a grafting material is most useful where strength is of primary importance, as in the ununited fractures of the shafts of the long bones. It may be used to advantage with cancellous bone which furnishes the osteogenetic medium. Cancellous bone as a grafting substance is preferable in the treatment of ununited fractures of the ends of the long bones and defects of bone caused by tumors or infection, for fusion of joints, fusion of the spine, and in correction of severe deformity by the open-wedge type of osteotomy.

In compound fractures with infection, early and complete healing of the wound by excision of scar, removal of sequestra, plastic procedures on the skin and soft parts, and by the use of the sulfonamides and penicillin, is of the utmost importance. Compound infected

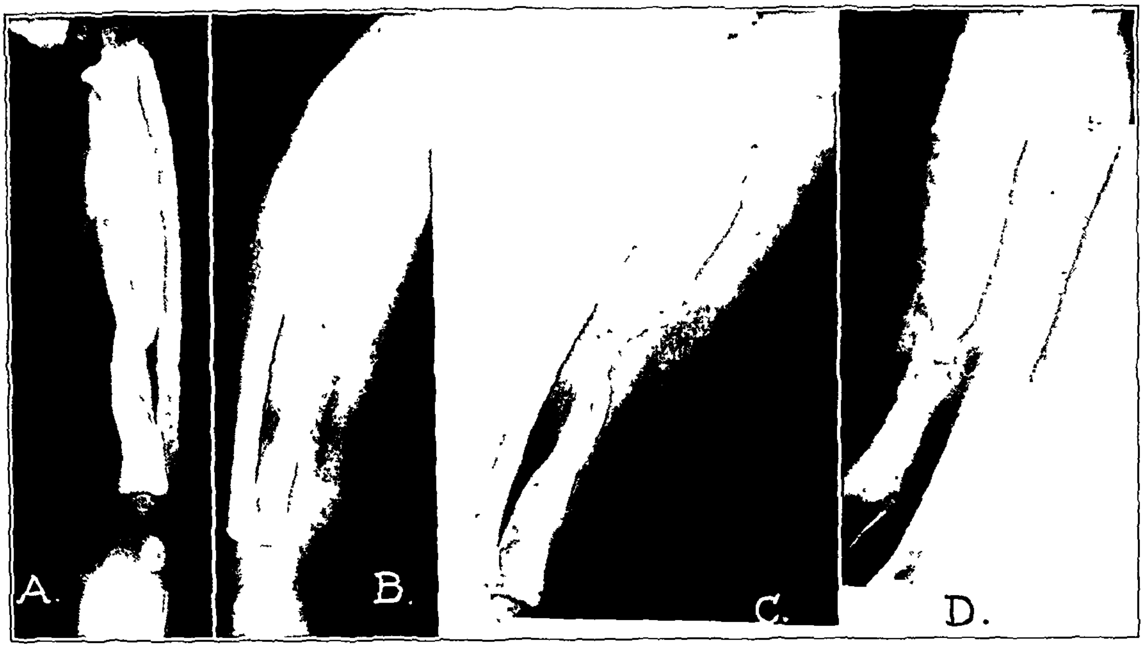

Fig. 21

A: Chronic osteomyelitis of the radius with massive sequestration.

B: After sequestrectomy and resection of involucrum.

C and *D*: Two months after grafting with cancellous bone.

E and *F*: Ten months after grafting, showing restoration of radius and its medullary canal.

It was of interest in observing these patients throughout the Ninth Service Command to note the type of fixation that was used. Internal fixation was obtained by wire, screws, or metal plates, while external fixation was secured by plaster-of-Paris or splints. It was the general opinion among the orthopaedic surgeons of the Command, as well as our own, that the less metal employed in these old infected wounds, the better. Not only was a flare-up of infection more common, but it was felt that the presence of metal, especially in the form of a large plate, definitely hindered the formation of bone, held the ends of the fragment apart, and thereby helped to prevent union of the fragments. If internal fixation was decided upon, it was felt that it should be regarded as a temporary expedient and that it should be removed after it had fulfilled its function.

In other army Centers, other methods have been used in the treatment of massive defects. At the meeting of The American Academy of Orthopaedic Surgeons in January 1946, Flanagan and Burem had an exhibit showing the technique of their method. Defects of the femur and tibia were obliterated by massive sliding grafts. It was our opinion that this method required an operation of considerable magnitude. Its use, we believe, should

Various theories have been advanced to explain the development of deformities in poliomyelitis. The early idea had been that they were brought about by the unopposed action of the muscles which were not affected. Lowman considered the cause of this deformity as an unbalanced action between the rotators of the flexed knee,—either from definite overaction on the part of the biceps, or "as a passive attitudinal deformity in which the external rotator has shortened with insufficient opposition on the part of the internal rotator". Bradford and Lovett state: "Volkmann . . . explained nearly all the deformities on mechanical grounds, urging that the deformities were developed partly by reason of the weight of the limbs concerned and the position which they assumed when at rest, and partly because of the muscular insufficiency of the affected limbs which allowed the articular surfaces to be subjected to an excessive pressure when brought into use, which had the effect of gradually pressing them into abnormal position". Yount felt that postural influences must be paramount in external rotation below the knee, and that muscle imbalance could not be the explanation. The grouping of paralyzed muscles at the knee which would lead to muscle imbalance would be paralysis of the internal rotators without involvement of the external rotators. Yount repeatedly observed this deformity when this grouping was not present. He postulated further that there was a pathological contracture of the tissues on the outer side of the knee, particularly of the iliotibial band, and not merely an overaction of the external rotator. He maintained "that the tensors of the fascia lata when in a state of contracture may be effective in producing external rotation of the tibia, though normally they have no such action".

The evidence submitted here seems to point to the mechanical factor as being of prime importance in the development of this deformity, associated with a definite grouping of muscle paralysis. *Furthermore, the facts presented support the belief that abnormal* external rotation of the leg will occur under the following circumstances; and that, in the absence of any one of these, this deformity is not likely to occur.

1. Complete paralysis of the internal rotators at the hip (in a few instances, slight power was present, rated at poor minus, or 10 per cent. muscle).
2. No support, or incomplete support, of the extremity during the first few months of illness, so that the entire lower extremity assumed the position of external rotation for a major portion of the time.
3. Complete or severe paralysis of the muscles at the knee. This included both the flexors and extensors, whose power was not better than poor, or 20 per cent. muscle.

The foregoing statements are based upon a study of the anatomy and mechanics of the knee joint and its supporting structures, and an analysis of 125 patients (or 250 extremities) at the New York State Reconstruction Home.

ANATOMY AND MECHANICS

It is not intended to review completely the entire anatomy of the structures around the knee, but rather to discuss those facts that are pertinent to the question presented.

The knee is a hinge joint, formed by the articulation of the lower end of the femur with the upper end of the tibia. The fibula is very firmly attached to the posterolateral surface of the upper end of the tibia by the anterior and posterior tibiofibular ligaments; so that, in movements at the knee joint, it forms a single mass unit with the upper end of the tibia.

The knee joint possesses flexion and extension in the sagittal plane, and inward and outward rotation in the transverse plane. This axial rotation occurs only in flexion; while in full extension, the joint is locked against it. At the end of extension the external rotation of the tibia on the femur, which is normally present, is checked by the tibial collateral ligament, which becomes taut[5], particularly in its posterior portion. The cruciate ligaments offer no check action to this motion, because they uncross during outward rotation. Furthermore, it has been shown that, when the cruciate ligaments are severed in full extension,

FIG. 23

Cancellous iliac bone graft between metacarpals.
A: Appearance of graft three months after placement.
B: Appearance of graft five months after placement and two months after specimen was taken for biopsy.
C: Appearance of graft two years after placement, showing medullary canal well established.

years old, with a compound fracture of the tibia with infection and loss of substance, a metal plate and iliac graft showed union and the formation of cortex and medulla in approximately one and one-half years (Fig. 22). In another case, in which a pure cancellous graft was placed between the first and second metacarpals, the cortical surfaces began to form in three months; after two years there was complete restoration of the marrow canal (Fig. 23).

If the area of union is subjected to strain before this differentiation occurs, especially at the center of the shaft, refracture is almost certain to occur (Fig. 24). It is our suggestion that it may be best to attempt to bring about union of the fragments by the use of a highly vascular media—namely, cancellous bone—by a first-stage operation, and then to take advantage of this highly vascular media by planting one or more cortical grafts so that they can be uniformly revascularized and replaced along their entire lengths, rather than at their upper and lower ends. We have had one such case in which bony union has occurred.

We wish to emphasize that in all these procedures of bone-grafting, the less metal used for internal fixation, the better. There is ample clinical evidence to show that infection is more frequent, and bone formation is impeded where the fragments are fixed by screws, bolts, wires, and particularly large metal plates. Furthermore, the site of insertion of a metal screw is often the first place to be invaded by granulations, which in turn cause absorption of bone. If the screw and fracture line are in proximity, a loss of continuity of bone substance is readily established, and, with minimal trauma, a refracture occurs. If screws are to be used, they should be placed as far from the fracture line as is consistent with adequate fixation. If plates are to be used, they should be removed at an early date to minimize the added risk of infection and interference with new-bone formation. However, in fractures of the shaft of the femur, we would suggest the avoidance of their use entirely and the substitution of plaster-of-Paris or splints with sufficient traction to maintain alignment.

In both civil and military life, the surgeon is faced with the problem of treatment of compound fractures involving the long bones, which are complicated by infection, the formation of cavities, and incomplete union. In the Military Service, these chronically in-

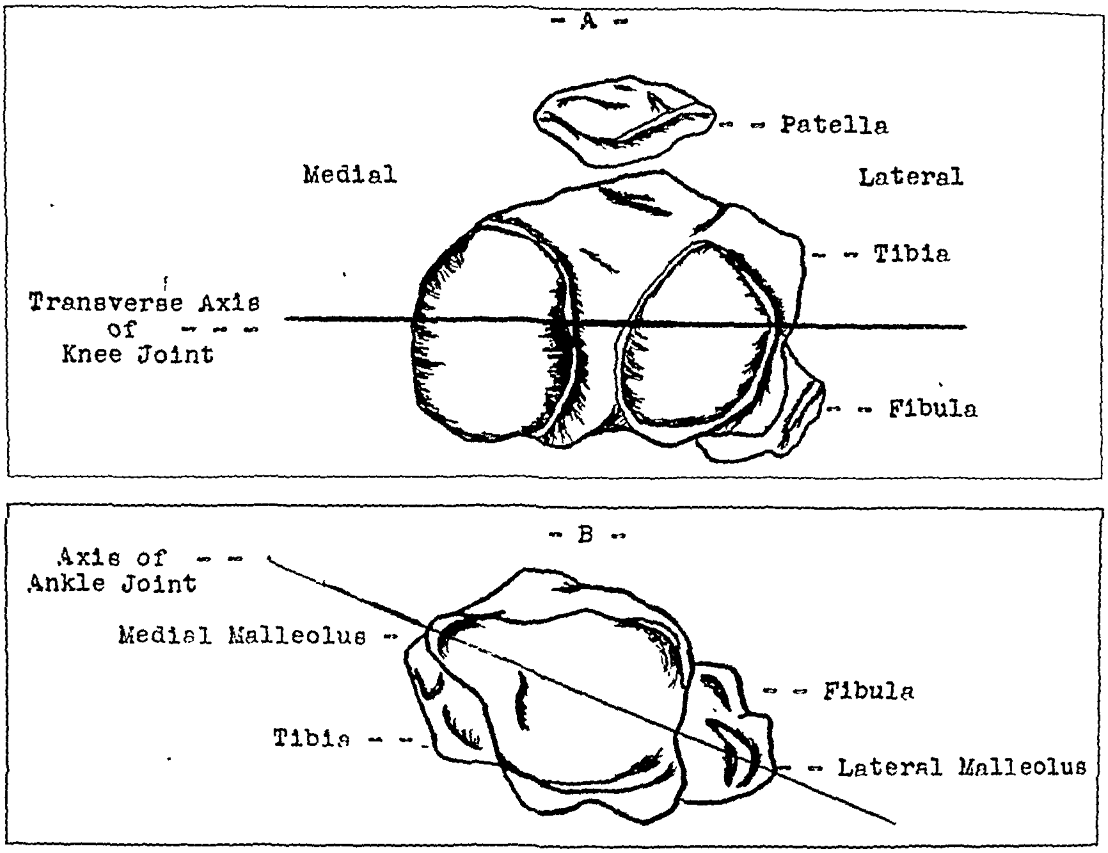

FIG. 3

A shows knee joint, as seen from above. *B* shows ankle joint, seen from below. Drawing demonstrates the angle of normal external rotation of the axis of the ankle joint to the transverse axis of the knee joint.

rest, either the external and internal rotators were of equal strength or the inner hamstrings were slightly stronger.

The role of the iliotibial band in this deformity is questionable. This structure inserts on a tubercle on the proximal surface of the tibia, mid-way between the apex of the patella and the head of the fibula. With the knee in full extension, its direction of pull is along the line of the lateral side of the knee, practically mid-way between the anterior and posterior planes; and mechanically it would cause abduction of the leg, rather than rotation, if it were contracted. Furthermore, if adaptive shortening of the iliotibial band were an important factor in this deformity, fasciotomy of the band with intermuscular stripping should release any resistance that it might offer to manual correction of rotation. This was not true in one of our patients, upon whom this operation was done bilaterally to correct hip-flexion contracture. Postoperatively, the severe external-rotation deformity (one leg to 70 degrees and the other to 50 degrees) remained unchanged, and could not be altered manually when the knees were fully extended.

In summarizing the discussion of the anatomy and mechanics, the following facts are emphasized: The fulcrum of axial rotation at the knee is medial to the mid-line of the joint, so that the greater weight mass is lateral. The joint presents more laxity when its supporting muscles are severely paralyzed, thus lessening the checkrein activity of the tibial collateral ligament to increased external rotation. As a result, when the entire lower extremity assumes a position of external rotation from the hip downward, the portion below the knee increases its external rotation above normal and gives rise to this deformity.

ANALYSIS OF CASES

One hundred and twenty-five patients were studied, ranging in age from seven to twenty-nine years. Younger children were not included, because it was felt that the history

fected cavities have been treated by excision of scar, curettement of their walls, and secondary plastic methods to obtain healing. Bone-grafting to fill the bone cavity has been delayed until firm healing has occurred.

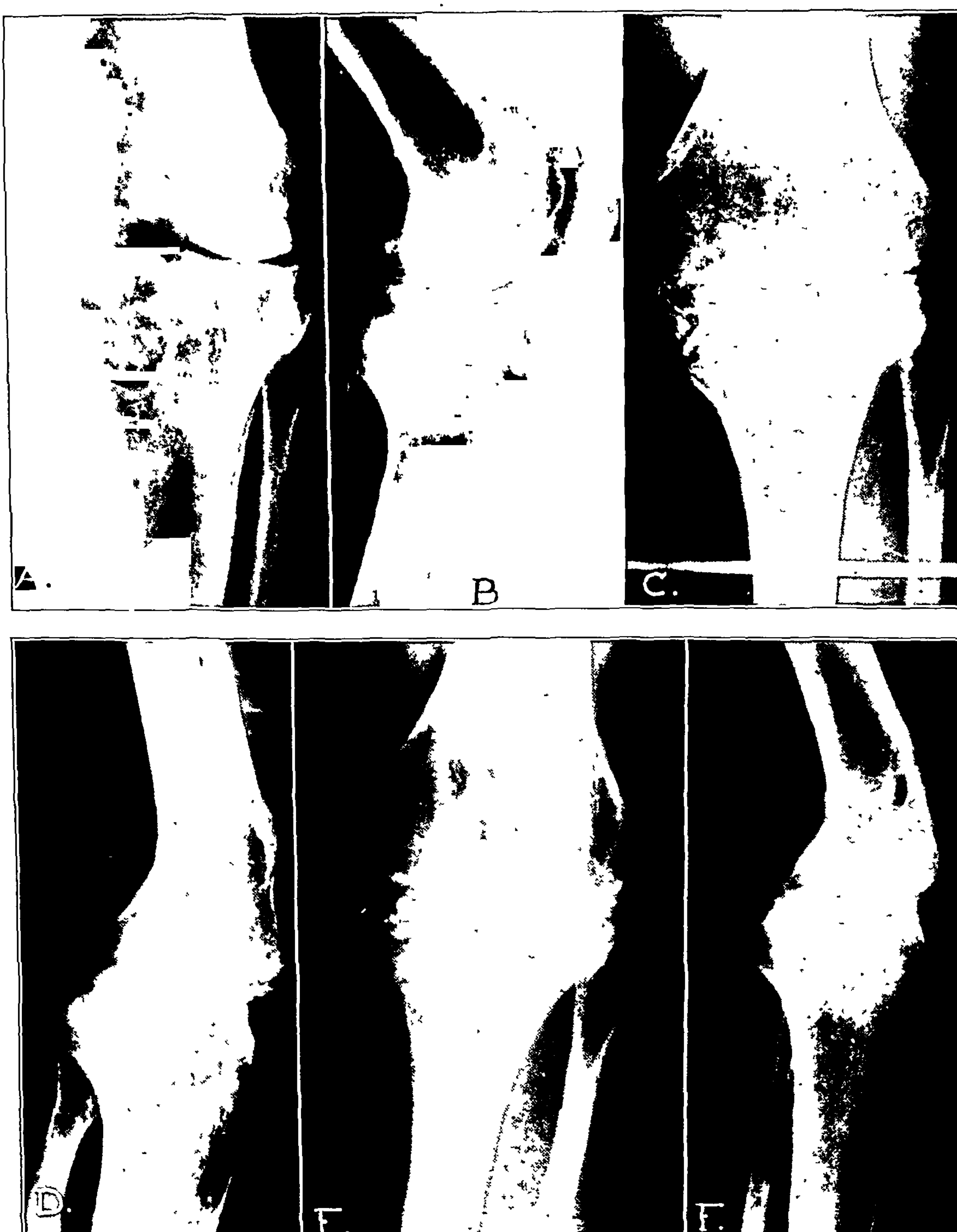

Fig. 25

A and *B*: Tuberculosis of knee joint with sinus and secondary infection. (Note extensive destruction of joint.)
C and *D*: Four months after excision of joint and filling of cavities with cancellous bone from the ilium.
E and *F*: Solid fusion of joint one year after the operation.

In certain cases, where obliteration of the cavities is difficult to obtain or where methods to cover them have failed, Rhinelander has resorted to filling them with pure cancellous bone with partial closure of the skin over the graft wherever possible, and the preoperative

TABLE I

Analysis of Cases of Paralysis of the Lower Extremities

Group	No. of Cases	Rotation		History of Support		
		First Leg	Second Leg	None	Good	Unreliable
A	3	Severe	Severe	2		1
	2	Severe	Moderate	2		
	4	Severe	Normal	2		2
	2	Moderate	Moderate	1		1
	9	Moderate	Normal	3	3	3
	26	Normal	Normal		19	7
B	1	Severe	Normal	1*		
	3	Moderate	Moderate	1	1	1
	3	Moderate	Normal	2*	1	
	8	Normal	Normal		6	2
C	2	Severe	Normal	1		1
	1	Moderate	Moderate		1	
	6	Normal	Normal		2	4
D	1	Severe	Normal			1
	6	Moderate	Normal	6		
	5	Normal	Normal		3	2
E	4	Normal	Normal		2	2
Total	86			21	38	27

* Support was used, but it was inadequate in the leg presenting the deformity.

degrees plus or minus 1.25 degrees of variation (Fig. 3). Steindler states that the angle is 30 degrees. Although the average in our series was 25 degrees, ranging up to 30, allowance has been made for error, because our method admittedly could not be so accurate as that used by Elftman. As a result, for the purposes of this study, the normal was considered to be as high as 35 degrees. Rotation of from 35 to 50 degrees was considered moderate, and 50 degrees or above was considered severe.

Eighty-six patients with poliomyelitis had severe or complete paralysis of one or both lower extremities. Thirty-seven of them demonstrated external-rotation deformity,—ten patients in both extremities and twenty-seven in one extremity. In one of these, the onset of poliomyelitis was in 1943; in twenty-two, in 1944; and in fourteen, in 1945,—about four months prior to this examination. A careful history was taken of the extent of support to the paralyzed extremity during the first four months of illness. Information was obtained as to whether a bed board, pillows, sandbags or posterior splints, with or without crossbars, were used to support the extremity and hold the foot in neutral rotation. A reliable history was obtained in fifty-nine cases, or 69 per cent. Notation was made of those who gave a definite history of support, those who had no support or whose support was not adequate for the major portion of the time, and those in whom the history was too indefinite to be considered.

Table I presents an analysis of those cases with complete or severe paralysis of one or both lower extremities. The extent of external rotation in each leg is recorded as severe, moderate, or normal. Notation is made of the extent of paralysis, with particular attention to the internal rotator of the hip and the muscles around the knee. Exceptions, which were few, are also noted (Figs. 4 and 5).

Group A includes the cases which showed zero muscle power in both lower extremities, including the hips. In six instances the external rotator at the hip, with or without the knee extensor and the hamstrings, showed slight power, rated as poor minus or poor.

The cases in *Group B* showed zero muscle power in one extremity and poor-minus power of the internal rotator of the hip, with no better than poor power throughout the rest of the other extremity. In six instances, fair power was present either in the knee extensor or the hamstrings.

fractures, with loss of substance, remain a difficult problem, although notable advances have been made in their treatment during the recent War. If there is moderate loss of substance, success has attended the use of dual or triple grafts of cortical bone, with cancellous bone alone, or with the two types used jointly. It is true, however, that, in many cases with extensive defects, healing across the gap may be incomplete, or fracture may occur through immature callus. In such cases several bone-grafting operations may be needed. In some instances, it is best to perform the operation in two stages. In the first stage, the gap is filled with cancellous bone to secure early union of the fragments and to provide a continually vascular bed to which the cortical grafts are applied at the time of the second operation. Uniform revascularization of the cortical grafts may then be secured with complete consolidation of the fracture.

In cases of non-union or cavity formation with infection where healing of the wound cannot be obtained, particularly in the ends of the long bones and the bones of the carpus and tarsus, it is worth while to use cancellous bone as a grafting material. In such cases, union of the fragments or obliteration of the cavity may be secured. It should be emphasized here that, in our experience, we have found cancellous bone to possess a high degree of viability in the presence of infection, particularly if penicillin is employed before and after the operation. On the contrary, a cortical graft seldom survives infection, and generally is extruded from the wound as a sequestrum.

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THE TREATMENT OF FRACTURES OF THE FEMUR IN A FIELD HOSPITAL

BY IVAR ALVIK, M.D.*, SANDVIKA, NORWAY

Although improved methods of emergency traction splinting and of treating shock have greatly reduced the mortality from combat fractures of the femur, management of the more difficult cases still constitutes a considerable problem. Treatment in the field must include measures to provide a maximum of immobilization of the fracture fragments, together with a minimum of interference with the transportation and nursing care of the patient.

A method of reduction and immobilization, devised at Field Hospital No. 1, has proved satisfactory in fulfilling these requirements, and has the additional advantage of facilitating active motion of the knee joint and of the ankle joint.

TECHNIQUE

The patient lies on a padded pelvic support, with the knee joint flexed to a right angle,

* Formerly Chief of Norwegian Field Hospital No. 1.

EXTERNAL ROTATION OF THE LEG IN POLIOMYELITIS

BY SAMUEL C. YACHNIN, M.D., PASSAIC, NEW JERSEY

From the New York State Reconstruction Home, West Haverstraw, New York

Major advances have been made, since 1900, in the knowledge and application of the principles of orthopaedic care in poliomyelitis. This is true, not only with respect to the surgical means of overcoming or improving disability, but also as regards the prevention of deformity. Lewin has postulated that no major deformity should be permitted to occur. Ruhräh has set forth the idea that "the causes for subsequent deformity develop early, and prevention should start at once". The recognition and application of these two principles will materially reduce the incidence of external rotation of the leg,—commonly called external torsion of the tibia. The author believes that this deformity develops early and can be prevented.

The existence and the importance of this deformity cannot be doubted, and have long been recognized by many orthopaedic surgeons. Lowman, who observed the work of Hoke in Atlanta, stated: "Many operated foot cases were relapsing because the rotation deformity had received no consideration". Bradford and Lovett stated: "There is a tendency to outward rotation of the tibia upon the femur in cases of long-standing paralysis of the leg. In this case the eversion of the foot in walking is a troublesome complication." Whitman noted the presence of outward rotation of the tibia in confirmed knock-knee. Hatt and Hough demonstrated the presence of tibial torsion in nineteen patients out of eighty-six with deformity around the knee. Smith described a case of equinovarus deformity, due to an imbalance of the lateral stabilizers, which was associated with abnormal "outward rotation or torsion of the entire tibia and fibula at the knee". He stated that the varus deformity was likely to recur after correction unless the torsion was overcome (Fig. 1). Crego and McCarroll analyzed recurrent deformities in 1100 consecutive stabilizations of paralytic feet. They noted that in eighteen out of forty-three instances, associated with other malformations in the remainder of the extremity, external torsion was responsible for the recurrent deformity, usually causing varus of the foot. In seventeen other cases in which external torsion was combined with knock-knee, either varus or valgus of the foot recurred. O'Donoghue reported that one of the major factors in the production of disability in children, as observed in a large orthopaedic clinic, had been "a definite rotation of the lower leg with a disturbance of relationship between the knee and ankle . . ."

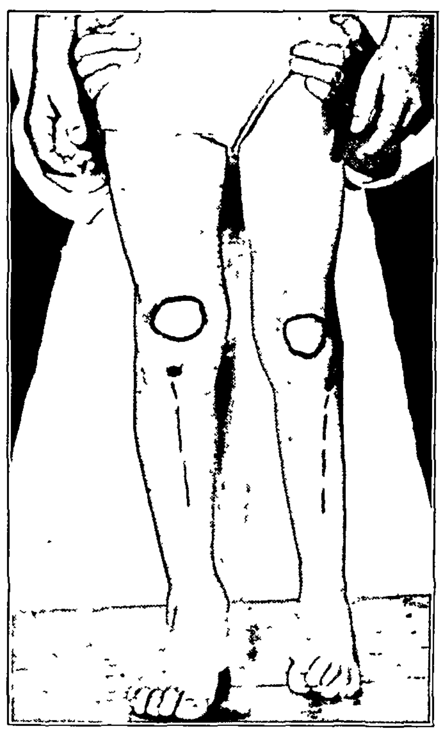

FIG. 1

This patient, whose poliomyelitis began in 1941, is ambulatory with a brace for the left ankle. The leg is in 45 degrees of external rotation. The patellae, tibial tubercles, and crests are outlined. Varus deformity of the foot is present, and is apt to recur after foot correction unless the external rotation is corrected by tibial osteotomy.

Thus we see that external rotation of the leg has been encountered quite frequently, and its importance has not been overlooked. Correction has been accomplished by simple osteotomy of the upper fourth of the tibia, or by the controlled rotation osteotomy described by O'Donoghue. It is not the purpose of this paper to discuss the treatment of this deformity, but rather to analyze its cause and the possibilities of its prevention.

SYMPOSIUM ON THE INTERVERTEBRAL DISC

INTRODUCTION *

BY ARTHUR G. DAVIS, M.D., ERIE, PENNSYLVANIA

In assembling this Symposium, it was the aim of the Chairman to determine, if possible, the points upon which there was general agreement, and to explore the possibilities of resolving differences in diagnostic approach and therapy. It seemed natural that a subject which was only ten years old should contain considerable divergence of opinion. Information concerning intervertebral-disc pathology was very meager prior to the revolutionary work of Barr and Mixter. In 1927, the writer had occasion to search the world literature for evidence of involvement of the intervertebral disc in spine injuries. In the whole mass of literature on spine injuries, only two references could be found to indicate that the disc was involved[1,5]. Having the results of this review of the literature in mind, the author made the observation, in a paper written in 1929, that the intervertebral disc appeared to be relatively invulnerable. No sooner had this observation been made than the monumental work of Schmorl and Junghanns appeared. Two other significant observations—namely, those of Goldthwait and Dandy—complete the significant information as of the year 1934. Up until this time, the cause of low-back pain with sciatica hovered largely between lumbosacral and sacro-iliac concepts.

The splendid work of Barr and Mixter, aided by Hampton, in 1934, therefore, struck the medical profession like a mental tidal wave. While this revolutionary concept involved the profession as a whole, the responsibility for its development devolved upon two special departments,—neurosurgery and orthopaedic surgery. It is not surprising that, with the different backgrounds involved in these two departments, the discovery of Barr and Mixter was interpreted differently.

In assembling this Symposium it was natural, therefore, to select the contributors from those who had had the longest experience with the subject in both fields of surgery, as well as from those in the related fields.

At the time this Symposium was presented, the author had treated approximately 250 cases of protruded intervertebral disc. From the eighty-four replies to a postcard questionnaire, it was learned that sixty-two patients had returned to their former occupations and eighteen had changed their occupations; 90 per cent. had been relieved of their sciatica. The remaining 10 per cent. had recurrences or low-back pain. The recurrences were usually at an interspace other than the one found to be involved at the former operation. It would appear that, because of the inability of the patient to assess his own symptoms, the only fully significant end-result study is the one which includes a personal interview and examination of the patient.

Experience with the frequency of recurrence in cases in which fusion was not done, the fact that protrusions occur largely in the two lowest intervertebral spaces, and the high frequency of unstable lumbosacral junctions have convinced the writer that in most cases, if not all, operation should include posterior fusion from the fourth lumbar vertebra to the sacrum. Approximately 150 consecutive cases have been treated in this manner, and recurrences have practically been eliminated.

It is hoped that this "taking of stock" and the recording of the salient facts on this subject at this time will serve to clear away some of the confusion in a very new field, and will help to reconcile widely divergent points of view between neurosurgeons and orthopaedic surgeons.

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

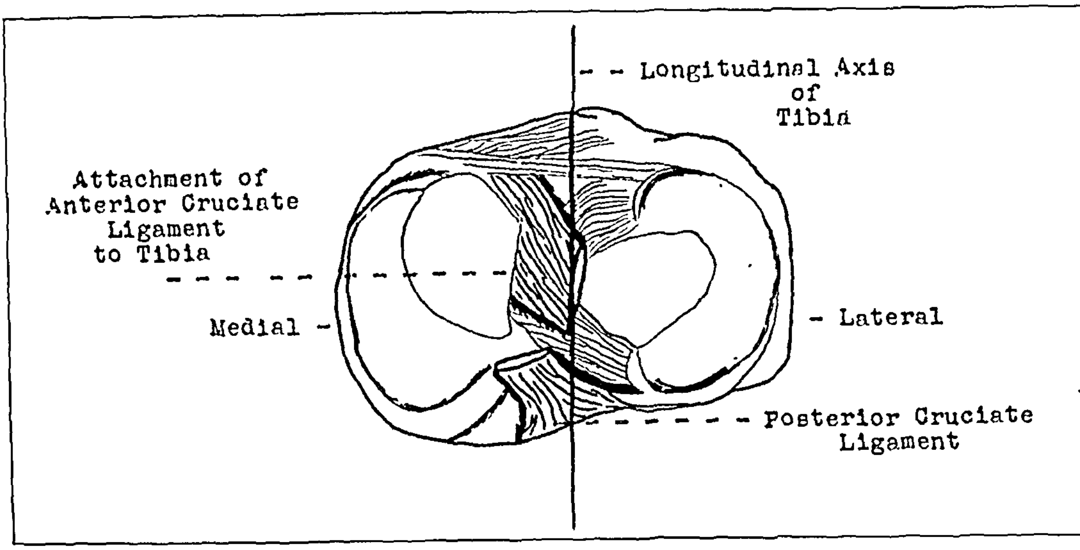

FIG. 2

Articular surface of the tibia, as seen from above. The anterior cruciate ligament is attached to the tibia close to the medial condyle of the tibia and medial to the longitudinal axis of the tibia.

stability is not altered except for slight anterior and posterior increased motion. The anterior cruciate ligament is somewhat taut in full extension.[17] It is important to note that its attachment to the tibia is medial and anterior to the intercondyloid eminence, a point which would seem to represent the fulcrum around which the axial rotation of the tibia occurs. Furthermore, Steindler states that: "The longitudinal axis of rotation . . . falls within the median condyle". This attachment of the anterior cruciate ligament is close to the medial condyle of the tibia, and medial to the longitudinal center of the tibia at its upper end (Fig. 2). Since the tibia and fibula must be considered as a single mass unit in motion, this fulcrum of axial rotation is even more medially placed in relation to the longitudinal center of the knee joint. Examination of the joint will show that the distance from the medial surface of the tibia to this fulcrum is three-eighths of the total transverse distance from the medial surface of the tibia to the lateral surface of the fibula. Thus it is apparent that the greater weight mass at the knee joint is external to the longitudinal center of rotation. If it were not for the stabilizing action of the ligamentous and muscular supporting structure, the leg would, of its own weight, fall into external rotation.

A detailed discussion of the anatomy of the supporting muscles around the knee is not required. The important point is that, when they are severely paralyzed, the joint suffers loss of stability. It has been shown in innumerable instances that the first and principal safeguard of the integrity of a joint is the muscle; and that, without it, the joint eventually would become relaxed and even dislocated. For instance, in cases of severe paralysis at the shoulder, the force of gravity is ample to bring about such a relaxation of the unprotected joint that subluxation and even real dislocation may result. This may also occur at the hip joint, particularly in instances of unprotected weight-bearing on a severely paralyzed hip. The knee joint, likewise, demonstrates definite increased laxity when its supporting muscles are severely paralyzed. Definitely increased motion, both anteroposteriorly and laterally, can be elicited. This is much more apparent in flexion. In full extension, when there is increased external rotation, the slack of the lax tibial collateral ligament is taken up at the extreme of rotation, so that undue motion on the inner side of the knee joint by abduction of the leg is difficult to demonstrate manually.

The theory that this deformity is caused by a muscle imbalance of the rotators of the knee postulates the presence of a paralytic grouping in which the biceps femoris is stronger than the inner hamstrings. Such a situation was found in only three of our cases. In the

The questionnaire was simply worded, so that "yes" or "no" could be checked in reply to the following questions:

1. Have you been free from pain in the back or in the leg?
2. Have you had any recurrence of pain?
3. How much time elapsed after operation before your pain was relieved?
4. Do you have any persistent numbness in the leg?
5. Do you have stiffness of the back or of the leg?
6. Do you have weakness of the back or of the leg?
7. Do you wear a back support?
8. Have you returned to work?
9. How long after the operation did you return to work?
10. What type of work are you doing?
11. Can you return for an examination?

A separate letter was enclosed, stating that the examination would be made by the author, and an appointment was made for the patient.

Questionnaires are not reliable for exact information. It was extremely difficult to evaluate the replies, because the answers did not qualify the degree of symptoms. Even the replies of those patients who were later examined did not give an accurate summation of their difficulties. However, by comparing the patients examined with their questionnaire answers, a fairly good estimate could be made of the replies of those patients who were not examined.

Few of the patients were entirely relieved of all symptoms so that they could be classified as having excellent results, able to perform their normal activities without complaint. However, of the 147 patients examined, 35 patients, or 23.8 per cent., were entirely well. The results in all patients were enumerated as good, improved, or not improved. The good results included those that were excellent, but most of the patients in this classification had some residual complaint, such as back stiffness, ache with excessive activity, or slight numbness in the foot or leg. They were not incapacitated, however. The patients in this group were very pleased with their results, were very much better than before operation, and did not consider the symptoms disabling. Those who were improved had much less pain and disability than before operation, but the complaints were of such a nature as to cause loss of time or to restrict activity, and the results could not be called good. Those who were unimproved were either at the same level of symptoms as before operation, or perhaps had some complication caused by the operation—such as foot-drop, rigidity from infection, or excessive weakness of the leg or back—which made them worse.

Of the entire series of 843 cases, 566, or 67 per cent., were males, and 277, or 33 per cent., were females. Of the 147 patients examined, 98, or 67 per cent., were males, and 49, or 33 per cent., were females.

The results in those examined were as follows:

	No. of Patients	*Per Cent.*
Good	99	67.5
Improved	25	17.0
Not improved	23	15.5
Totals	147	100.0

The results in those not examined were:

	No. of Patients	*Per Cent.*
Good	200	59.5
Improved	77	22.9
Not improved	59	17.6
Totals	336	100.0

Dandy changed his mode of attack in the disc operation, and, therefore, divided the series into three phases. Before January 1942, the loose fragment or sequestrum was re-

of their early treatment would be unreliable and would offer little of value to this study. The sexes were about equally represented. Thirty-nine cases were used as controls, as a means of determining the normal range of external rotation. All had normal lower extremities. Fourteen of these were not poliomyelitic patients; twenty-five had had poliomyelitis (nineteen with upper-extremity involvement and six with only mild weakness of one or both lower extremities), all muscles being fair to good at the time of the original examination. In addition, sixteen patients had severe unilateral involvement, in which the other extremity presented normal or only mild weakness of the muscles. Thus a normal range of external rotation was computed from the measurements of ninety-four extremities. This proved to be from 15 to 30 degrees, with an average of 25 degrees. Only eight measured more than 25 degrees, and fourteen less than 25 degrees.

The angle of external rotation was estimated by measuring the difference between the transverse axis of the knee joint and that of the ankle joint, with the knee in full extension. The transverse axis of the knee was taken as a line through the joint, parallel to the examining table, when the patella was in the mid-line with its anterior surface directly facing the ceiling. The axis of the ankle joint was taken as a line connecting the tips of the medial and lateral malleoli of the ankle, when the leg was held in the position described. A modification of an ordinary goniometer was used for the measurements.

Various investigators have studied the angle of deviation of the ankle joint from the transverse axis of the knee joint. Le Damany estimated the average in 100 tibiae to be 23.6 degrees: in 50 right tibiae as 25 degrees, and in 50 left tibiae as 22 degrees. Elftman studied thirty-five male cadavera, and found the average malleolar torsion to be 27.4

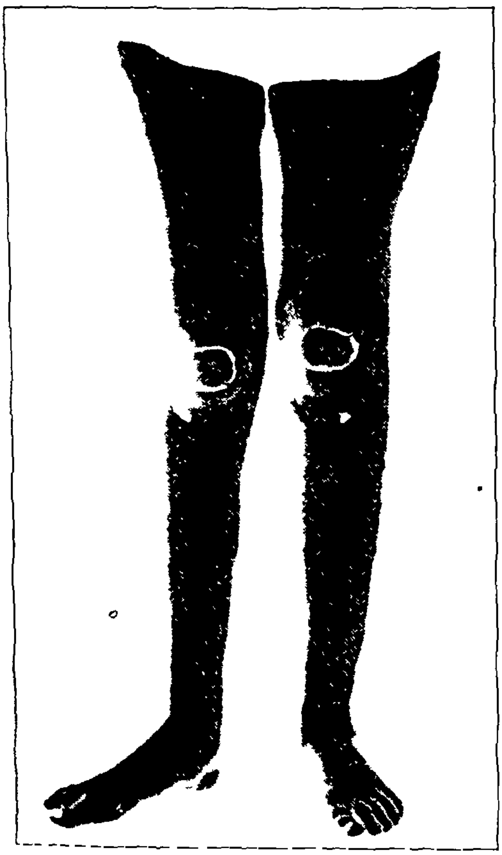

Fig. 4

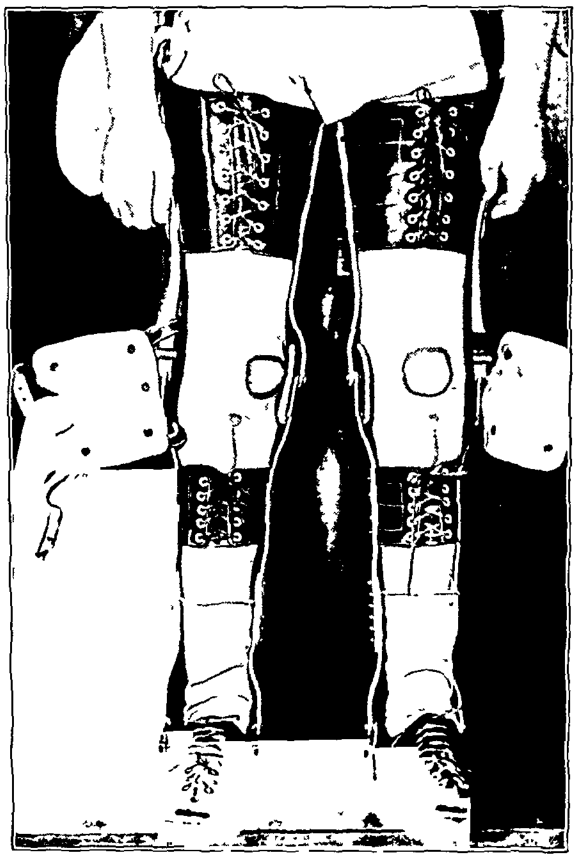

Fig. 5

Fig. 4: Patient with moderate deformity,—45 degrees of external rotation on the right.

Fig. 5: Case of severe deformity, with 60 degrees of external rotation on the right and 25 degrees on the left. The patient is wearing bilateral long caliper braces, attached to a pelvic band. The right brace holds the foot in correction, but the patella points medially and the tibial tubercle is shifted laterally.

cent. had narrowed interspaces, some of them associated with minor congenital anomalies, such as spina bifida and sacralized vertebrae. There was no distinct relationship between the narrowed space and the faulty disc. It was either at the level of the narrowed space or it was at the space above or below it. Five per cent. of the patients had arthritis of the lumbar spine or sacro-iliac region, or of both. Postoperative roentgenograms showed no appreciable change in the interspace involved. It is probably too soon to determine whether the space will collapse or show any evidence of bone fusion.

The location of the defective disc in the 147 patients examined was as follows:

Fourth lumbar vertebra	22 per cent.
Fifth lumbar vertebra	28 per cent.
Fourth and fifth lumbar vertebrae	40 per cent.
Third, fourth, and fifth lumbar vertebrae	7 per cent.
Lesions at higher levels	3 per cent.
	100 per cent.

Except in a few of the very early cases, the lesion was not localized by an opaque medium before operation.

COMMENT

In this series of cases, a neurosurgeon only removed the disc. Fusion of the posterior spine was not performed in any of the patients examined.

Some of the patients with residual complaints, due to tight muscles or faulty body mechanics, could be helped by appropriate physical therapy or by fusion.

Since 90 per cent. of the abnormal discs were at the fourth and fifth lumbar interspaces, it seemed unnecessary to use myelograms as an aid to the usual roentgenographic examination for low-back pain with sciatica.

SUMMARY

In a series of 843 operations for removal of an injured intervertebral disc, 67 per cent. of the patients were males.

The operation afforded good results in 67.5 per cent. of the patients examined. Of those not examined but surveyed by questionnaire, apparently good results had been obtained in 59.5 per cent.

Twenty patients required multiple operations for recurrences, in a series of 147 who returned for examination.

Roentgenographic interpretations are not reliable for accurate localization of the lesion.

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The cases in *Group C* showed poor minus or poor power throughout both lower extremities.

The cases in *Group D* presented one extremity with zero power throughout, and the other with fair or better power.

In *Group E* the cases showed one extremity with poor power throughout; normal power was present in the other.

An analysis of Table I showed that thirty-seven patients presented external-rotation deformity of one or both legs. Of this number, twenty-one, or about two thirds, gave a definite history of lack of support; six, or about one sixth, gave a history of adequate support; and ten, or about one fourth, gave an unreliable history.

Thus there seemed to be a definite association between the incidence of external-rotation deformity and a history of no support. When we analyze the group of cases which presented no deformity, despite severe paralysis of one or both lower extremities, the facts are even more significant: Forty-nine cases presented no deformity; of these, none gave a history of no support; thirty-two, or two thirds, gave a history of adequate support; and seventeen, or one third, gave an unreliable history.

It would appear, therefore, that adequate support to the lower extremity—sufficient to hold it in neutral rotation from the hip downward—will prevent the occurrence of external-rotation deformity of the leg.

DISCUSSION

The deformity described herein is more accurately termed external-rotation deformity of the leg than external torsion of the tibia. Clinical examination will demonstrate that the entire tibia and fibula are rotated outward, and that the tibial tubercle is definitely displaced laterally in relation to the patella. The rotation takes place through the knee joint, around the axis of the attachment of the anterior cruciate ligament on the superior surface of the tibia. When the supporting muscles around the knee are severely weakened or paralyzed, laxity of the tibial collateral ligament results. This reduces its action as a checkrein to increased external rotation. The deformity occurs during the early months of the illness, while the patient is still confined to bed. The internal rotators of the hip are severely weakened or paralyzed, thus allowing the unsupported lower extremity to assume the position of external rotation from the hip downward. When this abnormal position is not prevented by whatever mechanical means are at hand, and strict attention is not paid to continued support, this deformity will probably occur.

NOTE: The author wishes to thank Halford Hallock, M.D., Surgeon-in-Chief, for permission to publish this paper. Grateful acknowledgement is made to John C. McCauley, M.D., for his kindly interest and constructive criticism.

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because of failure to look for signs of its presence,—such as limitation of chest expansion, roentgenographic changes in the sacro-iliac joints, and elevation of the blood sedimentation rate.

One must consider and rule out in each suspected case of ruptured intervertebral disc a long list of diagnostic possibilities, including infectious processes, tumors, and mechanical lesions. Granted that ruptured intervertebral disc is the most common cause of intractable low-back pain and sciatic pain, it is not the only cause. No attempt will be made in this paper to review completely the characteristic clinical findings of ruptured intervertebral discs. The medical literature contains many excellent articles on this subject[3].

The problem of the accurate preoperative localization of the site of the lesion of a ruptured intervertebral disc has received a great deal of attention. It has been pointed out by numerous authors[3,8] that a lesion of the lumbosacral disc is often accompanied by paraesthesia or anaesthesia along the lateral border of the foot and the posterolateral aspect of the leg. The ankle jerk is usually diminished or absent, and there may be moderate to severe muscle weakness involving the gastrocnemius group. A lesion at the fourth lumbar disc often produces paraesthesia or anaesthesia of the great toe and the anterolateral aspect of the leg. There may be weakness or dorsiflexion of the great toe. The ankle jerk, although sometimes diminished or absent, is generally unaffected. The presence of a narrowed interspace, as shown in the lateral roentgenogram, will also aid in the localization of the lesion. Recently, Inman and Saunders have attempted to demonstrate that pain in the low back and buttocks, complained of in cases of ruptured intervertebral disc, has a segmental distribution which may be of localizing value. In the cases which we have studied preoperatively at the Massachusetts General Hospital in which the site of the lesion was verified at operation, it has been possible to predict the location of the lesion by clinical methods in approximately one half of the cases. Although this proportion of correct localization may be raised by refinements in the technique of examination, it has not yet attained a really satisfactory degree of accuracy.

Although certain surgeons are willing to operate upon their patients on the basis of clinical findings alone, the majority of surgeons throughout the United States believe that preoperative myelography is indicated in almost every instance. Such an examination, when positive, localizes the lesion, suggests additional areas to be explored, and rules out or visualizes spinal-cord tumors. It is of value even when negative; for, in those cases in which the clinical diagnosis is ruptured intervertebral disc and in which myelography fails to show a filling defect, the lesion, if present, will be found at the lumbosacral level[7] in almost every case. Therefore, this level should be explored first. At the Massachusetts General Hospital, pantopaque is the contrast medium in use at the present time, and it is used in practically every case preoperatively. It is injected, the roentgenographic examination is completed, and the pantopaque is removed by aspiration at one sitting. Although the technique of pantopaque examination is exacting, it is not excessively difficult; and it causes only transient discomfort which is usually not severe. If the pantopaque is removed after the examination, there is no reason to fear late sequelae. Its diagnostic accuracy has been attested by numerous investigators[4,10], the roentgenographic findings being positively correlated with the clinical findings in approximately 90 per cent. of the cases[10].

There is and will continue to be a great deal of interest in the proper criteria for the selection of cases for conservative and for operative treatment. If the presumptive diagnosis of ruptured intervertebral disc has been made by clinical examination, the surgeon must decide whether he is going to treat the patient conservatively or recommend operative removal of the protruded disc. The advantages and disadvantages of each type of treatment and the unique problems inherent in each individual case must be carefully considered. Operative treatment should, as a rule, be reserved for those patients who have intractable pain in spite of adequate, conservative treatment, and for those who show evidence of moderate to severe nerve-root compression as indicated by muscle weakness or paralysis, anaesthesia, and sphincter disturbance. A third group in whom operative treat-

and the hip to about 110 degrees (Fig. 1). The calf is supported by a wide cloth sling, suspended from the ceiling by a rope which parallels the longitudinal axis of the thigh; sufficient traction is exerted through this rope to correct the overriding. Débridement may now be performed, while an assistant steadies the suspended extremity. A second sling may then be placed behind the thigh, at the level of the fracture; any posterior angulation of the fragments should be slightly overcorrected. The reduction is observed by means of portable roentgenographic apparatus; adjustments of the traction are made; and the corrected position is maintained while a padded hip spica cast is applied. The cast should be quite stout; it may be strengthened about the back of the knee by a molded wire splint or a wooden reinforcement.

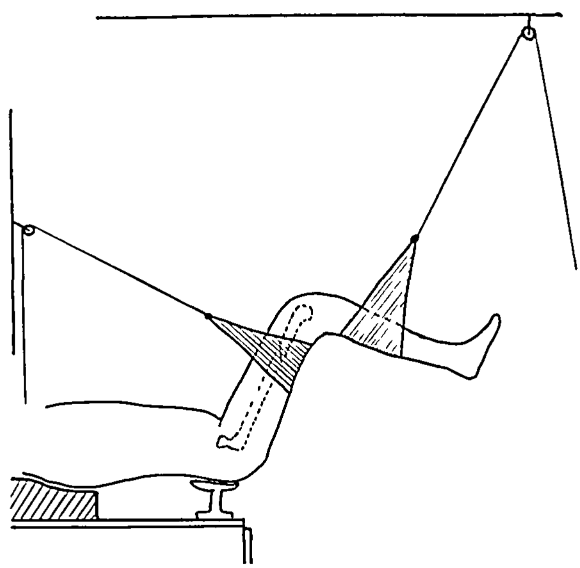

FIG. 1

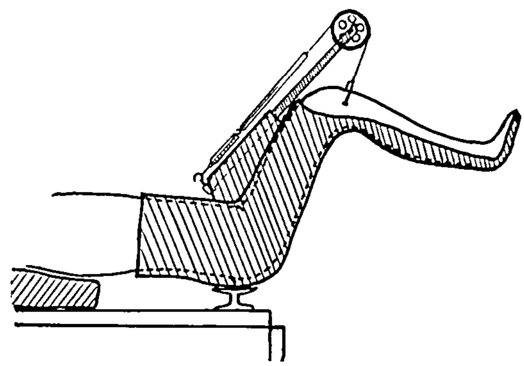

FIG. 2

Fig. 1: Shows patient lying on pelvic support, with slings supporting the extremity.
Fig. 2: Traction apparatus has been incorporated into the cast.

The plaster is now cut away from the anterior aspect of the extremity, from just above the knee downward; this permits motion in the knee and ankle. A traction apparatus is then incorporated into the cast (Fig. 2) to prevent loss of the reduction and the development of pressure ulcers. A Steinmann pin is driven through the tuberosity of the tibia, or better, through the distal end of the femur. It is important that motion take place between the pin and the clamp rather than between the pin and the bone; hence a pin of fair size is preferable to a wire. A splint, applied to the plaster on the anterior aspect of the thigh, extends to hold a large pulley in front of the knee. The rope attached to the Steinmann clamp passes over this pulley and is fastened to a strong piece of rubber tubing, folded according to thickness and strength. The proximal end of this tubing is hooked to the proximal end of the splint, in order to maintain traction. A spring balance may be inserted for measurement of the tension; it should then be replaced by a piece of rope of equal length.

The patient may now be transported on an ordinary stretcher. Adjustable crossed bars are attached to the handles of the stretcher, forming an angle in which the patient's limb, encased in plaster, may rest in the elevated position. If the patient is not to be transported, balanced suspension of his lower extremity and back will allow him to raise himself in bed without changing the position of the fragments.

Wedging of the cast to correct angulation of the fragments may be carried out after the countertraction bar on the anterior aspect of the thigh has been removed temporarily. Secondary operative procedures may be performed through a window in the cast. Changing the cast is accomplished readily, the position being maintained by use of the Steinmann pin for suspension of the extremity.

definitely significant statistically, but such evidence as we had then indicated that, in the series of cases in which spine fusion was done, the end results appeared to be somewhat better than in the cases where fusion was not done. Five years have elapsed since that study was completed, and it seems to us that it is worth while to report briefly an end-result study on a series of cases not reported previously. In February 1946, a questionnaire was sent to all of our patients who had been operated upon for ruptured disc in the years 1939 to 1943, inclusive; each was asked to fill out the questionnaire and to return in person, if possible, for a check-up clinical and roentgenographic examination.

The questionnaire which each patient filled out and signed was designed to give information of a specific nature which could be subjected to statistical analysis. The records of all patients who replied were abstracted. The check-up examinations and the analysis of the data represent the cooperative efforts of several participants, with a real attempt to eliminate personal bias. The 234 cases (Table I) include 102 with spine fusion and 132 without spine fusion. The questionnaire used is shown here.

SAMPLE QUESTIONNAIRE

Dear ———

We are checking up on the results obtained in the treatment of ruptured intervertebral disc, and should appreciate having your answers to the following questions:

1. Do you have any back pain? If there is any pain, is it mild? Moderate? Severe?
2. Does your back feel strong? Slightly weak? Moderately weak?
3. Can you stoop, twist, and lift without back discomfort? If not, describe briefly.
4. Do you have any pain in the leg? Any numbness? Any weakness? If so, describe briefly.
5. How soon after operation did your leg pain disappear?
6. Are you able to do a full day's work? If not, what is the reason?
7. Have you been forced to change your work or give up athletics because of back or leg symptoms?
8. What is your present occupation? How soon after operation did you return to work?
9. Have you had any attacks of leg or back pain since your operation? If so, describe, giving dates and treatment.

COMPARISON OF THE RESULTS IN CASES IN WHICH THE OPERATION INCLUDED SPINE FUSION AND THOSE WITHOUT FUSION, AS TABULATED FROM ANSWERS ON THE QUESTIONNAIRES RETURNED

1. Do you have back pain?

	Without Fusion No. of Cases	Without Fusion Per Cent.	With Fusion No. of Cases	With Fusion Per Cent
No back pain	59	45	61	60
Mild or moderate pain	60	45	31	30
Severe pain	13	10	10	10
	132	100	102	100

2. Does your back feel strong?

	Without Fusion No. of Cases	Without Fusion Per Cent	With Fusion No. of Cases	With Fusion Per Cent
Strong	49	37	59	58
Slightly or moderately weak	72	55	32	31
Very weak	11	8	5	5
Not sufficient data			6	6
	132	100	102	100

3. Can you stoop, twist, and lift without back discomfort?

	Without Fusion No. of Cases	Without Fusion Per Cent.	With Fusion No. of Cases	With Fusion Per Cent
Yes	79	60	69	68
No	53	40	30	29
Not sufficient data			3	3
	132	100	102	100

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END-RESULT STUDY OF THE INTERVERTEBRAL DISC *

BY RAYMOND E. LENHARD, M.D., BALTIMORE, MARYLAND

Although the intervertebral-disc lesion had been noted before the report of nineteen cases by Mixter and Barr in 1934, it was soon thereafter that the problem of the ruptured disc was attacked with enthusiasm, and that most of the operations were performed by neurosurgeons. This report pertains to a series of patients operated upon by Walter E. Dandy, M.D., of Baltimore. On numerous occasions his operations for disc injury had been discussed, and a year ago Dandy offered the author the privilege of communicating with his patients and of examining them for a postoperative follow-up.

Prior to 1941, Dandy doubted the frequency of ruptured disc as reported up to that time; but, after seeing many cases, he became convinced that all low-back pain, with or without sciatic pain, was caused by injury or abnormality of the intervertebral disc. During the years 1941 to 1944, inclusive, he operated upon 843 patients. In 1941 there were 117; in 1942, 204; in 1943, 292; and in 1944, 230. The operative technique has been described by Dandy, and consisted of removal of the injured disc after an excision of the ligamentum flavum on the side of the sciatic pain.

In March 1945, questionnaires were sent to all patients who had been operated upon; 513, or 60 per cent., returned the questionnaire, as requested. One hundred and forty-seven patients returned for examination.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

TABLE I

FOLLOW-UP STUDY *

Year	No. of Patients Operated Upon	Number for Whom End Results Were Obtained		
		Questionnaire Only	Questionnaire and Examination	Totals
1939	50	21	14	35
1940	57	17	14	31
1941	91	33	17	50
1942	93	35	19	54
1943	89	33	31	64
Totals	380	139	95	234

* The period of follow-up ranged from 2 to 7 years, with an average of 3.6 years.

sary weakening of the architecture of the spine; and poor postoperative management with neglect of proper rehabilitation. To the list of cases with poor treatment as the cause of failure, must be added a group of cases still carried as "ruptured disc" in spite of a negative exploration.

It should also be frankly recognized that most of these industrial-accident patients are laborers who, in the course of their ordinary work, subject the back to excessive strain. They cannot be expected to return to work after a disc operation in less than six months; and, among the older men who have arthritis or other complicating factors, a certain proportion will never return to full work. Certain others are poorly motivated, ignorant, and fearful. Psychoneurosis or constitutional inferiority states may produce a total failure in such men. However, proper selection of cases, proper diagnosis, and treatment give very satisfactory results in the majority of the cases, and the benefits of surgical treatment cannot be withheld from them.

TABLE II

END-RESULT STUDY IN COMPENSATION CASES

Follow-Up *		Back Pain			Back Strength		
Years	No. of Cases	Degree	No. of Cases	Per Cent.	Degree	No. of Cases	Per Cent.
7	3	None	12	50	Strong	12	50
6	3	Mild or moderate	9	38	Slight or moderate weakness	9	38
5	4						
4	5	Severe	3	12	Marked weakness	3	12
3	6						
2	3						
Totals	24		24	100		24	100

* Average time of follow-up was 5 years.

Of the 24 patients, 15 (62 per cent.) had no residual leg pain.

Answers to the question, "Are you able to do a full day's work?", were as follows:

Yes	17 (71 per cent.)
No	7 (29 per cent.)

Answers to the question, "Have you been forced to change your work or give up athletics?", were as follows:

Yes	9 (37 per cent.)
No	13 (54 per cent.)
No answer	2 (9 per cent.)

Four patients (17 per cent. of the cases) did not return to work after the operation.

Five patients (21 per cent. of the cases) had fusion operations. Of these, 3 are absolutely well; in 1 the operation was a total failure; and 1 did not have spine fusion at the time of the original operation. Fusion was done later for a weak back. The final result in this case is not yet known.

TABLE I

PATIENTS OPERATED UPON

	No. of Patients	Per Cent.
First period	117	13.9
Second period	355	42.1
Third period	371	44.0
Totals	843	100.0

TABLE II

RESULTS IN 147 PATIENTS EXAMINED

	Per Cent. of Patients	Good (*Per Cent.*)	Improved (*Per Cent.*)	Not Improved (*Per Cent.*)
First period	8.9	76.9	7.7	15.4
Second period	30.7	71.1	15 5	13.4
Third period	60.4	64.0	19.1	16.9

TABLE III

RESULTS IN 336 PATIENTS NOT EXAMINED

	Per Cent. of Patients	Good (*Per Cent.*)	Improved (*Per Cent.*)	Not Improved (*Per Cent.*)
First period	10.1	58.4	20.8	20 8
Second period	39.6	57.1	25.6	17 3
Third period	50.3	61.5	21.3	17.2

moved; between January 1942, and June 1943, a curettage or removal of the entire disc was done; and after June 1943, multiple discs were recognized and removed entirely. After operation the patient was usually able to leave the hospital in from ten to fourteen days with a light canvas support for the back, to be worn for approximately three months.

It was felt that the third procedure would give the best results, but an analysis of the statistics (Tables I, II, and III) showed that the results were not dependent upon the type of operative removal of the disc.

Recurrences of symptoms, and, therefore, supposedly recurrences of disc lesions, occurred in some of the patients. Of the 147 examined, twenty patients had multiple operations. Sixteen patients had two operations; of these, six were classified as having good results, four as improved, and six as not improved. Two patients had three operations,—one with improvement and one without improvement. Two patients had four operations and then had good results. In most of the patients who had multiple operations, the first operation was performed in the second period,—that is, with removal of the entire disc.

Of the patients who had more than one disc explored at the time of operation, many had "concealed" discs and disc protrusions. Twenty-five cases of concealed disc alone were found. Of these, fifteen were classified as good results, five as improved, and five as not improved.

The residual complaints in the patients examined were numbness in the leg, occasional cramping of the leg or foot, weakness of the back with excessive activity, or stiffness after being at rest. Some of the findings causing the complaints were postural back strain, arthritis, tight back muscles, and tight hamstrings. Similar complaints and physical findings, but of greater magnitude, were found in the improved and unimproved cases.

An analysis of the twenty-three unimproved cases showed ten patients with chronic back strain, six with chronic back strain who were also very neurotic, three with arthritis, two with foot-drop, and two with recurrences.

About 25 per cent. of the patients either had had no roentgenograms or the films could not be located. Another 25 per cent. had negative findings. Approximately 30 per

ward or turned slightly upon the unaffected side, it is important that the chest and abdominal respiratory excursion should be free and unrestricted. This may be ensured by placing a pillow crosswise at the pelvis and pillow rolls longitudinally beneath each shoulder, so as to remove the pressure from the anterior chest wall. The choice of anaesthetic appears to be unimportant. The operation may be carried out under spinal anaesthesia, supplemented by a second intraspinal injection toward the end of the operation, or under general anaesthesia. A routine blood transfusion helps to prevent shock. The fourth and fifth lumbar and the first sacral spinous processes and laminae are exposed by bilateral subperiosteal dissection. The spinous process of the fifth lumbar vertebra is cut off at its base, and the ligamentum flavum is dissected off the laminae at the appropriate site. As a rule, it is necessary to sacrifice a moderate amount of the two adjacent laminae without cutting either lamina completely across. The removal of the protruding portion of the ruptured disc usually presents no difficult problem. In order to prevent recurrence of protrusion at this same level, it is important to remove all remaining free portions of the nucleus pulposus. The sinus through which the ruptured portion of the disc has protruded should be enlarged sufficiently to allow the introduction of a pituitary rongeur, and repeated attempts should be made to remove all loose fragments of disc tissue. A small curette on a long, thin handle, set at a moderate angle, is also helpful in removing additional bits of loose disc tissue. Too vigorous or injudicious curettage of the intervertebral space is potentially dangerous and appears to be unnecessary.

Many surgeons routinely explore the lower two interspaces in every case. If an ur doubted rupture, sufficient in size and location to have caused the patient's symptoms, i exposed and removed at one interspace, it would seem unnecessary to explore the othe interspace routinely. After removal of the ruptured disc and adequate hemostasis, spin fusion is done. The technique now used by the writer varies in no essential detail fror that described by Bosworth. The base of the first sacral and the fourth lumbar spinou processes are undercut to receive the graft. By means of a curved osteotome, cuttin through the posterior margin of the articular facets on each side, the posterior surfaces o the laminae of the fourth and fifth lumbar and first sacral segments are turned back Through a second curved incision along the posterior half of the crest of the ilium, extending downward just lateral to the posterosuperior spine, the outer table of the ilium i exposed by subperiosteal dissection. By means of osteotomes, a graft of suitable size i removed from the outer table of the ilium, just below the crest. In addition to the graft long shavings of cancellous bone are removed from the ilium by a small hand gouge. The iliac graft is carefully notched at each end, and is inserted, medullary surface anterior, between the spinous processes of the fourth lumbar and the first sacral segment, with the patient's spine in the acutely flexed position. The operative table is then extended and, as the spine comes into the straight position, the graft is securely locked between the spinous processes. If it has been carefully fitted, it will be found to be held firmly in place, and cannot be displaced even on vigorous attempts. The additional grafts of cancellous bone are packed along the edges of the iliac graft, and the wounds are closed in the usual fashion. A plaster-of-Paris splint or a previously prepared jacket may be used to immobilize the spine postoperatively; but we have found that a simple canvas corset with re-enforcing steels in its posterior portion, which can be bent to follow the contour of the back, is very comfortable and gives adequate postoperative immobilization. The patient is kept flat in bed for three weeks after operation. He is turned regularly from side to side, and is allowed to lie for part of the time on his face. After the first week, bed exercises are begun to keep the muscles of the trunk and extremities in good tone. At the end of three weeks, the patient is allowed to be up, with the lumbar spine immobilized by a properly fitted back brace. It is important to maintain the lumbar spine in full extension at all times. Standing and walking probably cause less discomfort and strain on the lumbar spine than does sitting. Practically all patients are ambulatory and have been discharged from the hospital

RUPTURED INTERVERTEBRAL DISC AND SCIATIC PAIN *

BY JOSEPH S. BARR, M.D., BOSTON, MASSACHUSETTS

As students of the defects and diseases of the human frame, we are daily reminded that the truth is hard to come by, and that our knowledge of any medical subject is incomplete, defective, and capable of continually being increased. Therefore, our intellectual concepts require frequent re-examination and revision. We meet today to re-examine the present status of our knowledge with regard to intervertebral-disc lesions in the low lumbar spine. Fact and opinion are as closely related as cause and effect. None of us can acquire facts with regard to disc lesions without developing opinions as to their etiology, diagnosis, and treatment.

In this paper there will be reviewed some pertinent facts with regard to these lesions, which are well substantiated, and certain opinions will be expressed which are personal interpretations of questions which arise in all our minds.

The syndrome of the ruptured disc which, pressing on one or more of the nerve roots of the lumbosacral plexus, causes intractable sciatic pain, has been so well demonstrated that it is accepted and recognized by practically every physician today. Our knowledge of the syndrome is still incomplete, but it is increasing rapidly; and there is every indication that acrimonious debate and empirical speculation are giving way to agreement on the basis of documented and verified information. Although a "snap" diagnosis of this condition can be made in many cases from the history alone, it is unsound medical practice to indulge in hasty or slipshod methods. A careful, complete history and physical examination are indispensable to accurate diagnosis and treatment.

A ruptured intervertebral disc may cause no symptoms; it may produce a classical case with essentially all the usual signs and symptoms; or it may produce atypical and variable symptoms and signs. The presumptive diagnosis of ruptured intervertebral disc should be made clinically, not on the basis of a few signs and symptoms, but on all the available evidence,—that is, a complete history, physical examination, and the pertinent laboratory data. In many cases where the diagnosis is obscure, it will be helpful to repeat the examination, particularly during an exacerbation of the symptoms.

It is important to realize that patients with back pain, but no leg pain, may be suffering from a ruptured intervertebral disc; in some of these patients, "classic" symptoms and signs of sciatic pain will eventually develop. If the disc rupture is small or is placed far laterally, it may produce only local backache. Such a lesion will escape visualization by contrast myelography and it will in most instances escape visualization at the time of laminectomy[5]. It may be that, in a certain number of rather typical clinical cases in which exploration fails to reveal a ruptured disc, the patient with sciatic pain may actually have a ruptured disc, but placed so far laterally that it escapes detection. Whether unilateral facetectomy and a radical exploration should be done in such cases, or whether the surgeon should be content to do a spine fusion without facetectomy, is still an unsolved problem.

Disc lesions, however, are not the cause of all mechanical backaches. Acute ligamentous and muscle strains do occur. Backache due to postural defects is common. It is relieved by postural exercises and support, and it is unfavorably influenced by laminectomy in a search for a non-existent disc lesion. Ankylosing arthritis (Strümpell-Marie disease) can produce signs and symptoms almost indistinguishable clinically from a disc lesion, and in many early cases of this type of arthritis, operations have been performed

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THE DISC FACTOR IN LOW-BACK PAIN WITH OR WITHOUT SCIATICA*

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At the outset, let us assume that the protrusion of an intervertebral disc is a generally accepted anatomical, clinical, and pathological entity. It is true, however, that some men of excellent reputation wish to have little to do with such a condition, if, in fact, they even acknowledge the existence of such a lesion. The literature to date and the acceptance of protruded discs as a frequent cause of intractable low-back pain and sciatic pain by outstanding orthopaedic surgeons, neurologists, roentgenologists, and neurosurgeons would seem to establish definitely the validity of the lesion, as would also the thousands of patients who have been relieved of intense suffering after removal of the offending cartilage.

DIAGNOSIS OF PROTRUDED INTERVERTEBRAL DISC

The most important part in the successful handling of protruded intervertebral discs is their accurate diagnosis. As with most pathological lesions, experience is the best teacher; but the accumulated recorded experiences of those who have helped establish the disc syndrome should serve to lead anyone interested in the problem in the right direction and to minimize the percentage of false diagnoses[1,2,5,6,7,8,11,12,13,14,15,16].

History

A careful history of the patient's disability is oftentimes sufficient to warrant a presumptive diagnosis. The onset of trouble most often dates back to an injury to the lower part of the back. The injury may have been considered trivial, and often the patient may not have bothered to report it to his foreman or insurance company. Even if he is incapacitated, the period of incapacity frequently is short. However, subsequently, with or without further undue stress or strain to the back, recurrent attacks of more or less disabling backache occur, followed by extension of pain to the gluteal region and downward along the course of the sciatic nerve. The pain is typically of the nerve-root type. Rest in bed will often relieve it, but about a fourth of the patients have pain at night which awakens them from sleep and causes them to sit up or to walk the floor, to obtain any relief.

If the fragmented protruding disc remains in the mid-line and does not involve the nerve roots going to the lower extremities, there may be no sciatic pain or scoliosis. If the fragment of disc is small and shifts from side to side under the firm mid-portion of the posterior longitudinal ligament, then there may be alternating scoliosis without sciatic pain. If the mid-line protrusion of cartilage is large, there usually is backache plus alternating scoliosis and sciatic pain. This syndrome we have come to recognize. When the patient is disrobed, with the examiner sitting or standing behind him, the spinal column goes through a corkscrew type of motion, if the patient is asked to bend forward from his hips with his knees straight.

Even the more frequently encountered lateral disc protrusions with low-back pain and unilateral sciatic pain produce recurring backache for a long time before the onset of true sciatic pain. The author believes that this is due to stretching of the posterior longitudinal ligament without compression of the roots of the sciatic nerve. When the fragmented cartilage breaks through the posterior longitudinal ligament and actually comes into contact with the nerve root, the production of pain is the same as occurs in the presence of neoplastic compression. Without actual rupture of the posterior longitudinal ligament, the protruded intervertebral disc can compress and irritate the nerve root. As a

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ment appears to be indicated are those who have recurring episodes of low-back and sciatic pain of such frequency and intensity as to reduce definitely the patient's normal capacity for physical activity.

As we all know, there are innumerable methods of conservative treatment for low-back and sciatic pain, whether due to ruptured disc or some other cause. We suffer from an embarrassment of riches and it is difficult, on rational grounds, to select the proper method of treatment. Any of the methods will give excellent results in certain cases, and will fail in others. During the acute attack of sciatic pain, complete bed rest, with the spine in the position of greatest comfort, is indicated. It has been the writer's experience that these patients are most comfortable if the lumbar spine, hips, and knees are in the slightly flexed position. This position can easily be obtained by raising the head and the knee rest of the bed. The mattress should be firm. Adhesive strapping or a plaster jacket, applied with the lumbar spine slightly flexed, aids in immobilization. Adequate sedation, including morphine, in the acute phase is necessary to break the vicious cycle of pain and muscle spasm. After the acute attack has subsided, protection of the lumbar spine with a well-fitted corset or brace and retraining of the patient's muscles to ensure good posture may be indicated. Certain patients, by avoiding activities which produce severe strain on the lumbar spine, are able to prevent recurring episodes of low-back and sciatic pain. In other instances, the most trivial type of activity will precipitate a recurrence. Although manipulative procedures at times result in dramatic improvement in the acute symptoms, it seems illogical to expect any manipulative procedure to return a ruptured disc permanently to its normal position, and manipulation under anaesthesia appears to carry too great a risk to warrant recommending it. There is, however, a middle course between radical and ultraconservative attitudes, which we should seek to follow. In most cases, a trial of conservative treatment is indicated. If it fails within a reasonable period, say six weeks, to produce definite improvement in the patient's symptoms, operative treatment may be recommended with a clear conscience.

Now let us consider for a few minutes the important question of whether or not the operative treatment of ruptured intervertebral discs should include fusion of the spine. All of us will agree that any spinal segment from which a ruptured intervertebral disc has been removed surgically is no longer mechanically and anatomically normal. Narrowing of the disc space, with subluxation of articular facets and impingement of the facets on the pedicles, occurs in some cases and may be the forerunner of traumatic hypertrophic changes and local spur formation. The intervertebral foramina may be narrowed. In any operation for the removal of the disc, the dense ligamentum flavum must be removed. This ligament is an important structure, which helps to prevent hyperflexion of the spine. In certain instances, the surgeon must, in exposing the lesion, remove some or all of an articular facet, which may result in weakening or traumatizing the facet. These theoretical and practical considerations lead us to expect, *a priori*, that, in a certain proportion of disc cases, backache or weakness of the back will develop or continue after operative removal of the disc. On theoretical grounds alone, it would seem that a local fusion of the vertebrae adjacent to the ruptured disc is indicated. However, certain neurosurgeons have stoutly maintained that results in operative cases without fusion are excellent, and that fusion is rarely, if ever, indicated. It seems probable that these men have been so impressed by the obvious relief of the patient's acute sciatic pain that they have failed to look carefully for late evidence of a mechanically unsound back. There is no doubt that laminectomy without fusion gives excellent late end results, both as regards back symptoms and leg symptoms, in some of the cases. An analysis of our cases reported before The American Orthopaedic Association in 1940[1] shows that, of the patients with proved disc lesions who had had laminectomy with spine fusion, there was complete relief of sciatic pain in 91 per cent. and of back symptoms in 73 per cent. Of those patients who had had laminectomy without fusion, there was complete relief from sciatic pain in 69 per cent. and from back symptoms in 52 per cent. It was stated at that time that the series (94 cases) was too small to be

and she had hypalgesia in the first sacral dermatome. If a myelogram had not revealed the two tumors, she would have been operated upon for protrusion of the lumbosacral disc[10].

It has been contended by some that protruded intervertebral discs not only can be diagnosed by neurological methods, but that they can be accurately localized by determination of the dermatome involved, The author believes that many protruded discs cannot be localized by neurological methods. The following case is representative of many in which the neurological observations were misleading.

The patient, a white man of forty-one, was referred to the Clinic for relief of recurring low-back pain and right sciatic pain which had had its onset twenty-three years before. The patient had typical "first-sacral analgesia", which ordinarily would indicate a protrusion of the lumbosacral interspace. However, at operation, the lumbosacral disc was found to be normal and there was a typical protrusion of the fourth lumbar disc. The protrusion of the fourth lumbar disc was removed, and the patient was relieved of his pain. After operation, the analgesia in the area of distribution of the first sacral segment disappeared.

That a protruded intervertebral disc in the lower part of the lumbar region can compress the cauda equina sufficiently to produce ascending oedema of the cauda equina, with a dermatome level much higher than the actual site of the lesion, has been seen on many occasions. The following case illustrates this point.

A white man of thirty-five years was referred to the Mayo Clinic because of low-back pain and left sciatic pain. This man had sustained multiple injuries to his back, the first injury occurring twenty-two years before. Four years prior to his coming to the Clinic, a diagnosis of protruded disc had been made, but this had been denied by another physician, who had carried out a fasciotomy.

On neurological examination, the reflex of the left Achilles tendon was absent, the patellar reflex was decreased, and Kernig's sign and Lasègue's sign were elicited on the left. There was marked weakness on extension of the toes on the left, paraesthesia and decreased sensation of pain in the second-lumbar dermatome, and hyperaesthesia in the outer aspect of the calf and dorsum of the foot. There was also some atrophy of the muscles of the calf.

On the basis of the neurological examination, multiple protrusions of intervertebral discs were suspected. A roentgenogram of the spine showed a deformity in the air shadow opposite the fourth and fifth lumbar interspaces, consistent with a protruded intervertebral disc. The total protein in the cerebrospinal fluid was twenty milligrams per 100 cubic centimeters.

At operation the third, fourth, and fifth lumbar discs were explored. There was a classic protrusion of the lumbosacral disc on the left side. No lesion was present at the third and fourth interspaces. Postoperative examination showed that all of the patient's numbness had disappeared, except for slight paraesthesia around the left heel.

One of the first patients with a protruded disc seen by the author was a woman who had a large protrusion of the fourth lumbar disc, with paralysis of both lower extremities, bowels, and bladder, and a sensory level at the fifth-lumbar dermatome. Neurologically, it could not be determined with certainty whether the lesion was a neoplasm within the conus medullaris or an extramedullary lesion, compressing the cauda equina at a lower level. After removal of the protruded disc, the patient made a complete recovery.

Roentgenographic Examination

All patients who have intractable low-back pain and sciatic pain and all patients with evidence of nerve-root involvement should have roentgenograms of the appropriate portion of the spinal column before surgical intervention is undertaken, no matter how obvious the diagnosis seems to be.

A diagnosis of protruded intervertebral disc should not be made on the basis of a roentgenogram alone; but many other conditions which might produce a similar symptom complex may be excluded, or their presence may first be detected, by means of roentgenograms.

Examination of Cerebrospinal Fluid

All patients who are having enough trouble to warrant surgical operations on their backs should undergo lumbar puncture and should have the cerebrospinal fluid examined.

4. Do you have any pain in the leg? Any numbness? Any weakness?

	Without Fusion		With Fusion	
	No. of Cases	*Per Cent.*	*No. of Cases*	*Per Cent.*
Leg Pain				
Yes	54	41	26	25
No	77	58	74	73
Not sufficient data	1	1	2	2
	132	100	102	100
Leg Numbness				
Yes	61	46	39	38
No	66	50	59	58
Not sufficient data	5	4	4	4
	132	100	102	100
Leg Weakness				
Yes	41	31	13	13
No	80	61	62	61
Not sufficient data	11	8	27	26
	132	100	102	100

5. How soon after operation did your leg pain disappear?

The answer to this question varied, as might be expected, from "immediately" to "it has never completely disappeared". There was no apparent difference between the cases with fusion and those without fusion.

6. Are you able to do a full day's work?

	Without Fusion		With Fusion	
	No. of Cases	*Per Cent.*	*No. of Cases*	*Per Cent.*
Yes	83	63	64	63
No	31	23	16	16
Not sufficient data	18	14	22	21
	132	100	102	100

7. Have you been forced to change your work or give up athletics?

	Without Fusion		With Fusion	
	No. of Cases	*Per Cent.*	*No. of Cases*	*Per Cent.*
Yes	39	29	24	24
No	79	60	49	48
Not sufficient data	14	11	29	28
	132	100	102	100

The answers to questions 8 and 9 were not tabulated statistically.

A future detailed study of the causes of poor results and outright failures is planned. The results of the questionnaire as tabulated seem to indicate a modest but definite superiority of the results in fused cases over the unfused ones, when consideration is given to the factors of back pain and weakness, leg pain and weakness, and return to the type of work performed before the disability.

One patient, who had had a spine fusion, died of massive pulmonary embolism twenty-seven days after operation. There were no other deaths attributable to the operation in this series of 380 cases.

Considerable pessimism has been expressed concerning the results of operation for ruptured intervertebral disc in industrial accident or compensation cases[9]. End results were available in twenty-four such cases in this series. Fifty per cent. of these patients had absolutely no complaints, and 71 per cent. were back at full work. It is difficult to ascertain all the factors which may be involved in the poor results reported from v
sources. Some of them are: prolonged improper treatment or prolonged neglect,
in irreversible mental and physical deterioration; poor operative technique with

genographic observations alone. If there is a question as to the diagnosis of an intraspinal lesion, it is preferable to rely upon the history and physical examination rather than upon the roentgenographic findings.

Certainly, the value of roentgenography is not to be minimized, and frequently emphasis is placed on its negative value. That is, in a given case of low-back pain and sciatic pain with objective root characteristics, a negative roentgenogram of the spine is of great value, for it will exclude a neoplasm or other lesion situated above the fourth lumbar interspace. Operation may then be justified through a short incision, limited to the fourth and fifth lumbar interspaces, with a certainty of almost 100 per cent. that a protruded intervertebral disc will be found to be the cause of the disability. Without such visual aid, interpreted in the light of the history, physical and neurological examinations, and examination of the cerebrospinal fluid, error is likely to be great[18].

Rarely, tuberculosis at the lumbosacral space will give the classical picture—clinically, roentgenographically, and at the operating table—of a protruded intervertebral disc. If the dura mater is kept intact and the abscess is opened, no great harm is done; but if the meninges have been opened, tuberculous meningitis is likely to ensue.

THERAPY

Surgical Operation

All patients who have low-back pain and sciatic pain do not require operation. The patient, however, who is having sufficient pain and disability to interfere with his work, his hobbies, or his recreational activities deserves serious consideration. If, in spite of a well-planned and well-executed course of conservative therapy, the condition of the patient becomes worse, if he is unable to carry on his usual activities, or if muscle atrophy or eurological signs develop, then further investigation, with the idea of some surgical procedure in mind, is in order.

Operation of Choice

The operation which disturbs the body least and restores the structures most nearly to their normal condition is the operation of choice. In the vast majority of cases, the removal of a protruded intervertebral disc is a relatively simple surgical procedure, but sometimes it becomes an operation of considerable magnitude.

Adequate exposure is essential, but it is not necessary to sacrifice facets and to do extensive laminectomy, in the vast majority of cases. Patients who have unilateral sciatic pain, due to a protrusion at the fourth or fifth lumbar interspace, usually require unilateral reflection of the erector spinae at the level of protrusion. When the ligamentum flavum is resected, there usually is sufficient room in which to remove the protruded intervertebral disc without the sacrifice of any bone[9]. The involved nerve root is retracted between the laminae, and the fragmented disc tissue is removed. In protrusions at higher levels, or when there is marked narrowing of the interlaminal space, the margins of the laminae must be removed. In cases of bilateral sciatic involvement and those of backache only—usually due to mid-line protrusions—it is often necessary to shear off a portion of the adjacent spinous processes and of the laminae, and to remove the ligamentum flavum bilaterally, as well as the interspinous ligament, in order to obtain adequate exposure and to avoid trauma to the cauda equina while the protruded fibrocartilage is being removed. At the Mayo Clinic the entire disc is not removed.

Fusion

At the Mayo Clinic, when a "combined operation" is performed in conjunction with an orthopaedic surgeon, a tibial graft is employed, which is placed posteriorly, in contact with the laminae and spinous processes of the adjacent vertebrae. Regardless of whether the protruded intervertebral disc is at the fourth or fifth lumbar interspace, the ortho-

My personal experience at the United States Naval Hospital at Bethesda, Maryland, where I was stationed for sixteen months, may be of interest. Before my arrival, surgeons of the Neurosurgical Department had been operating upon ruptured discs, without doing spine fusions, with reasonably satisfactory results; but they were not entirely satisfied with their results and they, therefore, requested the Orthopaedic Service to cooperate with them in doing a series of cases by the combined operation, the neurosurgeons continuing to make the exposure and to remove the ruptured disc, the orthopaedic surgeons fusing the spine and caring for the patient postoperatively. All of the patients with ruptured discs at Bethesda during the period from August 1944 to December 1945 had this combined operation. The fusion was done according to Bosworth's technique, which will be described later. The graft was removed in some instances from the tibia; in others, from the ilium. The immediate convalescence in practically all cases was smooth and compared favorably with the cases done without spine fusion. Almost all of the officers were returned to full duty. As full duty for an enlisted man necessitated stooping, twisting, and lifting of heavy weights, it was deemed inadvisable in most instances to return the enlisted men to full duty. There was general agreement among the medical officers on the Neurosurgical and Orthopaedic Services that fusion by this technique did not unduly prolong convalescence, and that the early end results in the cases in which fusion was done compared favorably with a previous series of cases without fusion, cared for by the same surgeons.

Several patients who had been operated upon elsewhere were seen; they had had ruptured intervertebral discs removed and, at the time of operation, one of the articular facets had been sacrificed either wholly or in part. These patients had obtained relief from sciatic pain, but were totally disabled because of weakness and pain in the back. Spine fusion gave definite relief from their symptoms. In my opinion, any patient in whom a facetectomy has been done, either partial or complete, should have a spine fusion done at the same time. Unilateral facetectomy without fusion often produces severe, disabling symptoms.

The present status of the controversy over fusion may be summarized as follows:

There are valid theoretical considerations which indicate that any patient who has had a ruptured intervertebral disc removed cannot have a mechanically and anatomically normal spine at that level. End-result studies indicate that at least 50 per cent. of patients who have had a ruptured disc removed without spine fusion suffer to some degree from weakness or pain in the back. In some of these cases, the disability is severe and may, in fact, be completely incapacitating. Assuming that a technique of fusion can be developed which will not cause undue increase in operative risk or prolonged postoperative convalescence, it appears logical that fusion should be done in practically all cases.

Many types of arthrodesis are available, and any method will result in a reasonably high proportion of satisfactory fusion. A number of methods have been used in the cases reported from the Massachusetts General Hospital. Among the methods which have been tried are: (1) the Hibbs, (2) the Hibbs with the addition of an osteoperiosteal graft from the tibia, (3) a massive tibial graft, fixed to spinous processes by wiring, (4) an interbody fusion, and (5) the "clothespin" technique, as originally described by Gibson and subsequently modified by Bosworth. Fusion of the two adjacent vertebral bodies would appear, on theoretical grounds, to be the most satisfactory type of fusion. Technically it is difficult, however; and, after attempting it in a few cases, the author has abandoned it as being too dangerous. The double notched graft, described by Bosworth, which is placed between the spinous processes with the spine in flexion and which locks with the spine in extension, is now used. Although the bone for this graft can be removed from either the tibia or the ilium, the iliac graft recommended by Bosworth is superior; and, unless there is some contra-indication in an individual case, it is used routinely.

The technique of the combined operation need not be described in detail here, but a few points warrant consideration. As the patient is operated upon while lying face down-

removal of a protruded intervertebral disc should also undergo a fusion operation at the same time. Some surgeons feel that the combined operation would give added stability to the back; others undoubtedly feel that recurrent protrusions would thereby be avoided. In 1942, Ghormley, Love, and Young stated: "As far as we know, protruded intervertebral disks have not recurred after fusion . . ." Since that paper was published, experience has proved that the placing of a bone graft for fusion purposes does not, in all cases, prevent recurrence beneath the graft. Two such patients have been seen recently; one was operated upon in the Mayo Clinic and the other was operated upon elsewhere. Recurrent symptoms from a protruded intervertebral disc have been seen at the third lumbar interspace (an infrequent site of protrusion) after fusion of the fourth and fifth lumbar vertebrae to the sacrum, combined with removal of the more typical protrusion in the low lumbar area. One wonders whether or not fusion of the lumbosacral region caused more stress to be applied at the interspace just above the upper end of the graft, with resultant protrusion.

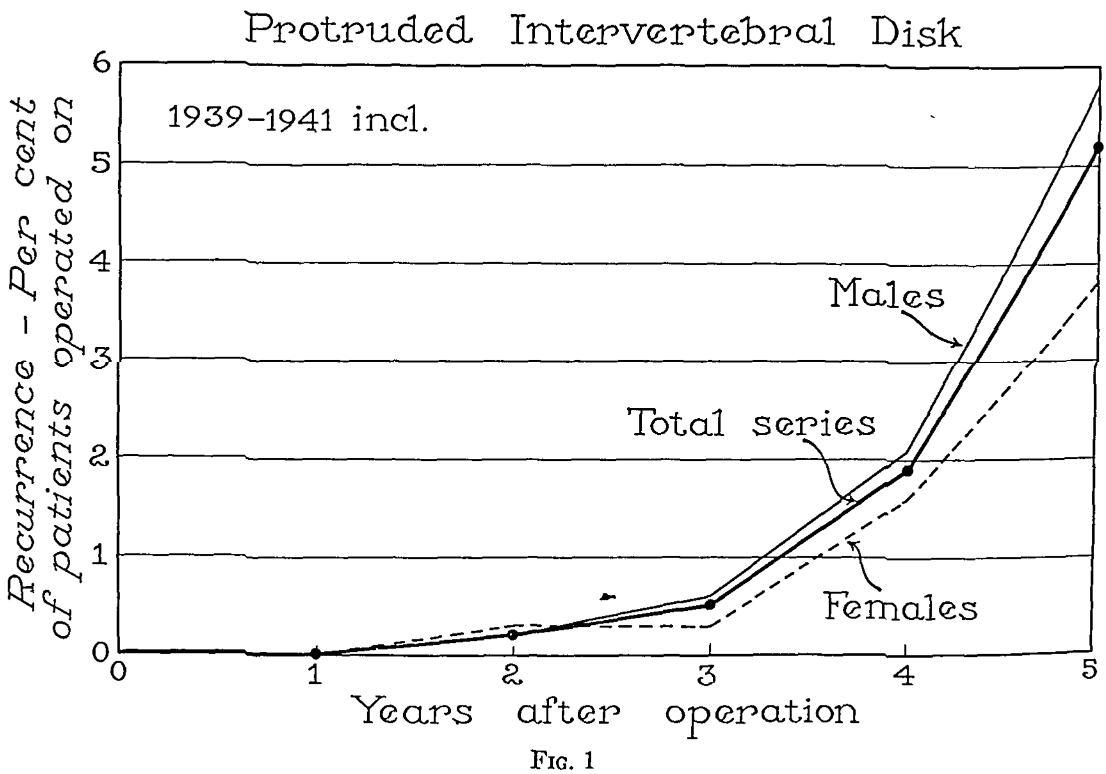

FIG. 1
The percentage rate of recurrence of protruded intervertebral discs, up to five years after operation, among males and females and for the total series of patients.

When there are definite indications for bone-grafting, and no definite contra-indications (secondary operation in the presence of infection, for instance) this operation should be done; but routine bone-grafting is not justified in the light of the author's experience up to the present.

FOLLOW-UP STUDY OF 1,217 PATIENTS OPERATED UPON FOR PROTRUDED INTERVERTEBRAL DISCS IN 1939, 1940, AND 1941

The foregoing portion of this paper is based largely on the author's experience and opinion, with which the other members of the Neurosurgical Section may or may not agree. The analytical report that follows is based on a study of the records of 1,217 patients, operated upon because of protruded intervertebral discs by all the surgeons in the Section on Neurological Surgery of the Mayo Clinic during 1939, 1940, and 1941. Those patients who underwent a "combined operation" were operated upon by a neurosurgeon and one of the members of the Section on Orthopaedics. The statistics, based on the study of a composite group of cases, were compiled by the Division of Biometry and Medical Sta-

within four weeks of the time of operation. The back brace is worn from four to six months after operation. The patient is allowed to resume all activity, including strenuous athletics, six months after operation.

SUMMARY AND CONCLUSIONS

Within the past fifteen years the medical profession has recognized the existence of a syndrome characterized by low-back and sciatic pain, due to protrusion of a ruptured intervertebral disc with pressure on one or more roots of the lumbosacral plexus. The clinical diagnosis in the typical case presents no particular problem. The localization of the lesion by contrast myelography and the technique of its removal by partial laminectomy have become standard procedures. It appears probable that the trend is toward fusion of the spine, at the time of laminectomy, in an increasing number of these cases. The thesis that every patient should have a spine fusion done at the time of laminectomy is tenable. As operative technique improves, the difficulties of the combined operation tend to disappear, and it seems probable that the combined operation will, in the near future, be the operation of choice for the majority of patients.

There is every reason to maintain a conservative attitude toward the operative removal of ruptured intervertebral discs. An operation of this magnitude is not without some risk, and it is not invariably successful. The conscientious surgeon and the average patient will be much happier to have tried conservative treatment for a period of time before resorting to operative interference. The principles of rest and immobilization, adequate sedation during the acute phase of the process, followed by protection of the low back from undue strain, and postural rehabilitation appear to be the essential parts of a conservative regimen.

NOTE All of the members of the Orthopaedic and Neurological Services of the Massachusetts General Hospital have cooperated in this end-result study. W J Mixter, M D, Charles S Kubik, M D, and Carroll Larson, M D, have given valuable assistance to the author

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In the group of cases studied, forty-seven patients had recurrent* protruded discs; forty-five of these patients had undergone the original operation at the Mayo Clinic and two had been operated upon elsewhere. Accumulative recurrence rates, percentages, and analyses according to sex and age are shown in Tables II and III and in Figure 1. Of the forty-seven patients who had recurrent protruded discs, twenty-four, or 51 per cent., also underwent the fusion procedure at the second operation, when the protruded disc was removed.

Sixteen of these patients subsequently were operated upon elsewhere. Seven underwent the fusion operation; of these seven, one stated that he was "no better", one was receiving shock treatments for a nervous disturbance, and a third was "still lame". Six of the sixteen patients who subsequently were operated upon elsewhere had one or more protruded discs removed, after having undergone removal of a protruded intervertebral disc at the Mayo Clinic. One patient said that "adhesions" had been found at his sub sequent operation, and that he was still having pain. One patient was operated upon whil in another country, because of pain for which no cause was found and for which no relie was obtained. One patient was "reoperated" upon, but the observations were not reported The reports for these sixteen cases are not very enlightening. They serve only to indicat that the discomfort was not relieved and that the patients were willing to undergo additional surgical procedures with the hope of obtaining relief.

The results obtained are not so good as we should like. That is, we should like to be able to report a higher percentage of complete relief five years after removal of a protrudec intervertebral disc. We do, however, consider the results satisfactory. With greater knowledge today, we can more satisfactorily select those patients who require surgica intervention and can apply the type of surgical treatment that is best suited to the particular condition. Therefore, better results are anticipated in the future. There will always be some patients, however, who fail to obtain complete relief from the measures under consideration. Backache is one of the commonest complaints of man, and since it is at times very difficult for the physician to determine cause and effect, how much more difficult it must be for the layman to determine whether his backache is caused by a protruded intervertebral disc, or by fatigue or other factors.

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* Further protrusion of disc substance at the same space at which the original protrusion had occurred.

result of compression by fragments of the disc, the nerve root becomes oedematous and enlarged, and ultimately adheres to the posterior longitudinal ligament and the protruded disc. The extradural vessels become engorged and contribute further to compression and irritation of the root. Removal of a protruded intervertebral disc with relief of low-back pain and sciatic pain has been performed on more than one patient who previously had been operated upon elsewhere, after a diagnosis of angioma of the root or spinal cord, because of this extradural congestion. True angioma of the spinal cord is very rare, yet extradural congestion and enlargement of vessels associated with protruded intervertebral discs are common.

After the stage of nerve-root compression and irritation, the ligamentum flavum becomes thickened and fibrotic[3], probably as a result of altered body mechanics (that is, scoliosis, loss of normal lumbar lordosis, and the like). This thickened ligament, lying as it does posterior to the nerve root and filling the space between the adjacent laminae, further encroaches upon the spinal canal and compresses the enlarged hyperirritable nerve root.

Physical Examination

The physical examination is second only to the history in helping to arrive at a diagnosis. The patient should be examined while disrobed, in a well-lighted room, and his gait should be observed very carefully. Any patient who has a protruded intervertebral disc and is not paralyzed—no matter how great the pain—should be able to stand beside his bed so that his posture can be observed. The patient usually guards his spinal motions, and frequently walks with a limp and with a list of the trunk, either away from or toward the painful side. The back usually is flattened, with loss of normal lumbar lordosis, and the erector spinae muscles are in spasm. All motions of the lower part of the back may be limited; lateral bending in the direction of the list is usually greater than toward the opposite side; and hyperextension is painful. This latter motion, if forced, may even cause the patient to collapse. Usually there is local tenderness in the region of the spinous processes of the fourth and fifth lumbar vertebrae. The result of the straight-leg-raising test is almost always positive on the side on which pain occurs and, when the opposite extremity is elevated in cases of unilateral sciatic pain, the extent of motion is at times limited, with reference of pain to the involved opposite member. Kernig's sign is usually elicited.

In the vast majority of cases, a diagnosis of protruded intervertebral disc can be made or ruled out by this time, but a neurological examination also should be made.

Neurological Examination

The neurological observations[17], in cases of lumbar protruded intervertebral disc not complicated by paraplegia, usually are minimum; they consist, in the main, of diminution or absence of the Achilles reflex, with or without slight sensory changes in the skin of the outer side of the leg and the outer and upper surfaces of the foot. Loss of motor power is infrequent, although some degree of atrophy of the calf muscles is not uncommon. Occasionally, complete foot-drop is seen, resulting from a lesion involving one nerve root. There is so much variation in the formation of the lumbosacral plexus and the lower part of the back that space-taking lesions cannot be localized consistently in this region by the neurological method. Frequently, the Achilles reflex is absent when protrusion of the fourth lumbar disc has occurred, and often it is present when protrusion of the fifth disc has been sustained. Protruded discs are often seen in patients who have four or six lumbar vertebrae and consequently only four lumbar discs or, in the latter case, an extra lumbar disc. Similarly, intraspinal neoplasms sometimes give the same neurological picture as protruded intervertebral discs. In one case, that of a woman who had suffered low-back pain and left sciatic pain intermittently for six years, two neurofibromata were removed from one nerve root opposite the second lumbar vertebra. The left ankle jerk was

TABLE I

LESIONS OF CARTILAGE PLATE IN CONTROL SPECIMENS

Decade	Nuclear Extension	Schmorl's Nodes	Vascularization
Second	0	0	0
Third	0	0	0
Fourth	4	2	2
Fifth	3	1	0
Sixth	5	1	0
Seventh	4	2	2

METHOD AND MATERIAL

For the purposes of the present study 182 discs, removed from 166 patients, were examined. All material was fixed in 10 per cent. formalin; sections were cut from paraffin blocks and stained with hematoxylin and eosin, and with Capri blue. Capri blue is a metachromic dye which stains collagen and connective-tissue mucin an intense blue, and brings out fibrillar structure in considerable detail. For purposes of control, forty discs, removed completely with their adjacent vertebral bodies, were obtained from the fifth lumbar, first-sacral level of cases upon which autopsies had been done. These specimens were removed from individuals of various ages with apparently normal backs. They were also fixed in formalin before sections were taken in the mid-sagittal plane. Examinations were then made of the gross specimen and of microscopic sections, by the staining techniques just mentioned. Follow-up studies of the surgical cases were conducted by mail, with a questionnaire designed to obtain the desired information as completely as possible. In many cases a letter accompanied the returned form.

CONTROL STUDIES

The intervertebral disc is composed of three essential interrelated components,—the cartilage plate, the annulus fibrosus, and the nucleus pulposus. Pathological changes in one will inevitably be reflected by changes in the others[4]. Since they are histologically distinct structures, they will be considered separately.

Cartilage Plate

This refers to the thin layer of hyaline cartilage, similar to articular cartilage, which borders the end plate of cancellous bone of the vertebral body. Centrally it is prominent, but marginally, with the exception of the posterior surface, it fades out into the annulus fibrosus, where the latter structure is attached to the elevated epiphyseal ring. Posteriorly the ring is deficient, and the cartilage plate reaches the posterior margin of the vertebral body. The cartilage plate is adherent to the spicules of cancellous bone through a thin layer of calcified cartilage. Between the spicules, the cartilage plate is in contact with the marrow, through which it receives nutrient material. Before the third decade, vascular channels are seen in the cartilage plate[2,3,7,8,9], extending from the marrow spaces. After this they disappear, leaving minute scars. These areas have been considered by some[2,3,21] to be points of weakness, through which nuclear material may extend to form the defect so well described by Schmorl. This, however, is an unlikely probability, which is given little credence by most observers[2,3]. Aside from these vascular channels, the entire disc is an avascular structure.

The cartilage cells are arranged irregularly, but show a general tendency toward arrangement in horizontal rows, particularly near the points of attachment of the annulus fibrosus.

The functions of the cartilage plate are twofold: First, it serves as a point of origin for the inner fibers of the annulus fibrosus; and, second, it acts as a barrier, along with a thin layer of annulus fibers, between the nucleus pulposus and the spongiosa.

Protruded discs rarely produce subarachnoid block, so that, if a block is found, other lesions, particularly neoplasms, immediately come into the differential diagnosis. In about two thirds of the cases of protruded intervertebral discs, the protein content will be forty milligrams or more per 100 cubic centimeters. A value for protein in the cerebrospinal fluid of more than 100 milligrams per 100 cubic centimeters usually means that a neoplasm, rather than a protruded intervertebral disc, is present[10]. In the presence of an unusually large protrusion, complete subarachnoid block, with a high protein content in the cerebrospinal fluid, may be found. In such cases the patient is paralyzed, and usually the paralysis was of sudden onset.

Use of Contrast Media in the Subarachnoid Space

If errors in diagnosis are to be kept to a minimum and the operative procedure best suited to the individual case is to be employed (both of which are necessary for the best end results), the lumbar portion of the spinal canal should be visualized prior to the operative removal of a protruded intervertebral disc. The oldest and most satisfactory method is to introduce radiopaque oil (lipiodol) into the subarachnoid space. This method is the most nearly accurate; in experienced hands, few protruded intervertebral discs should be missed and false positives should be infrequent. The introduction of air or oxygen into the subarachnoid space (a method which the author uses almost exclusively) is by no means so accurate as the use of lipiodol in delineating intraspinal space-taking lesions, but the roentgenogram, when interpreted in the light of the history and other observations, serves admirably in the diagnosis of protruded intervertebral discs.

The value of pantopaque myelography lies somewhere between that of lipiodol and air. The author's limited experience with pantopaque suggests that the percentage of error is much greater in the negatives and false positives than it is when lipiodol is employed. Both lipiodol and pantopaque, if used intraspinally, should be removed later. Pantopaque lends itself much better to aspiration than does lipiodol. Air and oxygen are absorbed and leave no opaque substance which may be seen in subsequent roentgenograms[18].

INTRASPINAL LESIONS, OTHER THAN PROTRUDED DISCS, CAUSING SCIATIC PAIN

A protruded intervertebral disc is the commonest intraspinal lesion that produces sciatic pain. Hypertrophic arthritis, spondylolisthesis, spondylolysis, old fractures and dislocations, tumors of the spinal cord and nerve roots, metastatic bone lesions, tuberculosis of the spinal column, and thickening and fibrosis of the ligamenta flava also produce sciatic pain; but the frequency with which operative interference is necessary in this miscellaneous group of conditions is small in comparison to that for protruded intervertebral disc.

In distinguishing the many lesions that may deform the roentgenographic shadow in myelograms, certain well-known criteria are available. For instance, the intervertebral discs are anterior to the dural sac, and protrusions of discs usually produce, in the roentgenograms, an anterior extradural type of defect, opposite the space between the two vertebral bodies. Since the ligamenta flava are posterior and lateral to the dura mater, thickening and fibrosis of these structures usually produce a lateral or bilateral type of constriction of the contrast medium at the interlaminal interspace. Tumors of the spinal cord are always intradural and those of the nerve roots are chiefly so; and defects due to such lesions are more likely to be opposite the vertebral bodies, even though the shadow of the lesion may extend to or across the interspace. The deformity in the myelogram, produced by spondylolisthesis of Grade 2 or more, is oftentimes indistinguishable from that produced by a protruded intervertebral disc.

The occurrence of a protruded intervertebral disc in association with spondylolisthesis has, in our experience, been uncommon; and the differential diagnosis prior to surgical exploration has been extremely difficult to make.

It seems unwise to advise an operation for an intraspinal lesion on the basis of roent-

TABLE II

AGE DISTRIBUTION IN SURGICAL CASES

Decade	Number	Per Cent
Second	5	3
Third	25	15
Fourth	62	37
Fifth	45	27
Sixth	25	15
Seventh	4	3
Totals	166	100

After the second decade and occasionally during it, a central fissuring appears within the nucleus, which progresses to cavitation. This becomes more apparent during fixation with its attendant dehydration. Schmorl believed this to be a rudimentary attempt at the formation of a joint space, but this does not appear to be a tenable supposition[16]. When examined microscopically, no suggestion of a synovial lining is seen, and the space is found to be the result of a degenerative change in the nucleus, which has an amorphous, granular, acellular appearance. This central degeneration increases gradually, some of the nuclei from the seventh decade being composed entirely of this necrotic-looking material. This change has been claimed by most authors[1,4,16] to be the result of progressive desiccation.

Cellular degeneration is also commonly seen, and some evidence of it was found in all of these specimens. As age increases, a progressive increase in fibrous character occurs, with decrease in the mucoid stroma. Focal deposits of calcium salts are seen; rarely, calcification of the entire nucleus occurs[5,6].

In none of the postmortem specimens examined was posterior or anterior protrusion of the nucleus pulposus found. However, in three of the four cases in which granulation tissue was invading intraspongious protrusions, this granulation tissue extended into the nucleus pulposus itself.

Two of the six discs in which Schmorl's nodes were present showed marked narrowing, which undoubtedly was the result of loss of considerable nuclear material. This same narrowing may occur in anterior or posterior herniations, if a sufficient portion of the nucleus is involved.

Diseases producing demineralization of the vertebral bodies, such as osteoporosis, osteomalacia, and metastatic neoplasm, may, if the nucleus retains its elasticity and the cartilage plate remains intact, result in an expansion of the nucleus with widening of the disc and production of the so-called "fish vertebrae"[1]. Two examples of this were found in the present group. A similar type of change was observed by Schmorl and by Beadle in adolescent spines; they considered this to be the result of developmental defects, chiefly in the cartilage plate, because this structure was unable to resist the "turgor" of the nucleus. This type of expansion was not observed by the authors.

In none of these discs could oedema of significant degree be demonstrated.

STUDIES OF SURGICAL MATERIAL

Of the 166 patients from whom material was obtained at operation, 60 per cent. were males and 40 per cent. were females. The youngest patient was thirteen years, the oldest

TABLE III

COMPOSITE TABLE OF MICROSCOPIC FINDINGS IN 166 SURGICAL CASES (182 DISCS)

Pathological Change	Cartilage Plate		Annulus Fibrosus	Nucleus Pulposus		
	Nuclear Extension	Vascularization	Scarring	Granular Degeneration	Fibroblastic Proliferation	Vascularization
Number	12	7	51	90	59	49
Per Cent.	6.6	3.8	28	49	32	27

paedic surgeon usually fuses the last two lumbar vertebrae to the first two sacral segments.

Some orthopaedic surgeons have contended that, even if a protruded intervertebral disc were present, a fusion operation would relieve low-back pain and sciatic pain. Some lumbosacral protrusions—possibly even some at the fourth lumbar interspace—undoubtedly have been cured by a massive bone graft, applied to support the interspace at which the protrusion had occurred. This is not inconsistent with our conception of the pathological appearance and pathogenesis of protruded intervertebral discs, for the protruded fragment of disc is often very oedematous, and the compressed nerve root usually is enlarged and oedematous at the time of operation for the removal of a protruded disc[2]. Likewise, the extradural vessels about the nerve root usually are congested at the time of operation. If the interspace is sufficiently splinted and the patient remains in the hospital for a sufficient time after application of the bone graft, the oedema of the protruded cartilage and the nerve root, and the congestion of the extradural vessels may subside sufficiently to relieve the nerve root of compression. Patients have required operative intervention, however, with removal of a protruded disc from beneath the bone graft which had previously been applied. The following case is representative.

A patient was operated upon at the Mayo Clinic on January 23, 1942, at which time, because of a diagnosis of lumbosacral arthritis, she underwent application of a bilateral massive bone graft, which extended on each side of the spinous processes from the laminae of the fourth lumbar vertebra down to and including the upper two sacral segments.

The patient required another operation on February 19, 1945, because relief had not been obtained and because at that time she was experiencing, in addition to low-back pain, bilateral sciatic pain. The third, fourth, and fifth lumbar discs were explored, and typical protrusion was found at the fourth lumbar interspace. The protrusion was in the mid-line and was irritating the nerve roots on both sides.

RECURRENCE OF PROTRUDED INTERVERTEBRAL DISCS

At least three months should be set aside for convalescence and reconditioning of the muscles of the back. After removal of a protruded intervertebral disc, recurrence can take place; but, fortunately, recurrent protrusions are not common. There is, as far as the author knows, no absolute way to prevent a recurrence at the same site or the occurrence of another protrusion at a different interspace. When a patient has recurrent nerve-root symptoms after removal of a protruded intervertebral disc, usually there is further protrusion of fibrocartilage from the same interspace; rarely, another disc is involved. Several surgeons have recommended the removal of the entire disc to avoid recurrence. Even if this were possible, it would be fraught with grave dangers in the hands of the surgeon who performs this operation only occasionally.

Some orthopaedic surgeons have expressed the opinion that all patients who undergo

TABLE I

DISTRIBUTION ACCORDING TO AGE AND SEX IN 1,217 PATIENTS OPERATED UPON FOR PROTRUDED INTERVERTEBRAL DISC FROM 1939 TO 1941, INCLUSIVE

Age (*Years*)	Total Patients		Males		Females	
	Number	Per Cent.	Number	Per Cent.	Number	Per Cent.
10 to 19	25	2.1	20	2.3	5	1.4
20 to 29	198	16.3	137	16.1	61	16.8
30 to 39	430	35.3	301	35.2	129	35.5
40 to 49	371	30.5	252	29.5	119	32.8
50 to 59	160	13.1	118	13.8	42	11.6
60 to 69	33	2.7	26	3.1	7	1.9
Totals	1,217	100	854	100	363	100
Averages	39.4 years (16 to 68 years)		39.4 years (16 to 68 years)		39.2 years (16 to 67 years)	

TABLE V

END RESULTS

	Herniated		Bulging		Softened		Total	
	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.	No.	Per Cent.
Asymptomatic	19	38.7	5	20	5	31.3	29	32.2
Moderate relief								
Pain in back	17	34.7	12	48	9	56.3	38	42.2
Pain in leg	3	6.2	0	0	0	0	3	3.3
Pain in leg and back	4	8.1	3	12	1	6.2	8	8.8
No relief	6	12.3	5	20	1	6.2	12	13.3
Compensation cases								
Relief	7		5		2		14	
No relief	1		2				3	

Cartilage Plate

Since the amount of hyaline cartilage varied with the vigor and frequency with which the curette was used, the amount seen in sections was a small proportion of the total cartilage plate. Undoubtedly in many of these discs, lesions in the cartilage plate were present, although we could not identify them. It is interesting that extensions of nucleus pulposus into cartilage plate, indeed, small Schmorl's nodes, can coexist with posterior or posterolateral herniations of the nucleus. This certainly suggests the possibility that the presence of granulation tissue in the nucleus pulposus need not be evidence that tearing of the annulus has occurred posteriorly.

Annulus Fibrosus

With rupture of the outer lamellae of the annulus fibrosus posteriorly, the remaining fibers frequently stretch over the protruding tissue of the nucleus pulposus. It is to be expected that scarring might occur, particularly marginally, and this is indeed the case. The age at which this process occurs is variable, the extremes being young granulation tissue and typical old avascular, relatively acellular fibrous tissue. Deucher and Love mention that, in most of their material, a loss of the regular course of the annulus fibers could be demonstrated. Since attachments of fibers possessing the same tension and elasticity are torn, this loss is to be anticipated and could be demonstrated in all of our cases.

In a few cases, focal deposits of calcium were found. Hyalinization of collagen fibers was encountered frequently, but no true necrosis was seen.

Nucleus Pulposus

The most striking change noted in the pathological material, as in the postmortem group, was the stroma degeneration ascribed to desiccation. This peculiar amorphous granular appearance, with loss of fibrillar structure, was noted in significant amounts in 49 per cent. of the discs studied. Reference to Table IV will show that this by no means was seen only in the older age groups, in which it is anticipated. Material taken from several patients in the second decade showed surprisingly large areas of this degeneration.

Cellular degeneration was also encountered frequently; whether this change occurs as a result of impaired nourishment, or whether, as in the control group, it is an aging phenomenon, cannot be definitely stated. Some cellular degeneration can be found in almost any disc examined; accordingly, no tabulation of this change has been made.

Focal deposits of calcium within the nucleus were occasionally found, and one case in this series consisted entirely of a calcified nucleus pulposus. Fibroblastic proliferation, with or without vascularization, approximated the incidence of scarring in the annulus fibrosus.

Oedema, mentioned so prominently in Deucher and Love's work and occurring in 22 per cent. of their cases, was not considered a significant finding in these studies. Upon

TABLE II

ANALYSIS OF ACCUMULATIVE RECURRENCE RATES, ACCORDING TO SEX, IN CASES OF PROTRUDED INTERVERTEBRAL DISC

Time Since First Operation (*Years*)	Accumulative Recurrence Rates*		
	Total Series (*Per Cent.*)	Males (*Per Cent.*)	Females (*Per Cent.*)
1	0	0	0
2	0.2	0.2	0.3
3	0.5	0.6	0.3
4	1.9	2.1	1.6
5	5.2	5.8	3.8

* The curves given in Figure 1 were prepared from these percentages.

TABLE III

ANALYSIS OF ACCUMULATIVE RECURRENCE RATES, ACCORDING TO AGE GROUPS, IN CASES OF PROTRUDED INTERVERTEBRAL DISC

Time Since First Operation (*Years*)	Accumulative Recurrence Rates, Expressed in Percentages, According to Age			
	20 to 29 Years	30 to 39 Years	40 to 49 Years	50 to 59 Years
1	0	0	0	0
2	1.3	0	0	0
3	2.0	0.3	0	0
4	3.6	1.8	1.2	0.9
5	8.2	5.1	4.4	4.2

tistics of the Mayo Clinic, under the direction of Robert P. Gage. With four or more neurosurgeons operating, there were, of course, variations in the technique as to myelography, operative removal of the protruded disc, and postoperative care of the patient.

Of the 1,217 patients operated upon for protruded intervertebral discs during the years 1939 to 1941, inclusive, three died in the hospital,—a fatality rate of 0.25 per cent. Among these patients, 854, or 70 per cent., were males, and 363, or 30 per cent., were females. The distribution according to age and sex is given in Table I. One hundred and forty-eight patients had undergone a "combined operation" originally; this group constituted 12.2 per cent. of the total series.

Of the 1,217 patients, 987, or 81 per cent., were traced either by questionnaire or by interview during a recent visit to the Clinic. Answers to questionnaires are not the best means of evaluating the results accurately, but they do have value, in the absence of individual re-examination, for such a large series of patients who were literally scattered throughout the world (as a result of World War II) at the time of this follow-up study.

The patients were asked: "Have you been relieved of the pain for which your operation was performed?" Among those who had had a protruded intervertebral disc removed, but had not undergone the fusion operation, 53.7 per cent. answered "yes"; 36.7 per cent. said they had obtained partial relief. Thus, the percentage of those benefited is 90.4, whereas 9.6 per cent. said they had obtained no benefit from the operation.

The patients were asked if they had any pain in their backs or legs. Of those who had undergone simple removal of protruded discs, 38.5 per cent. answered "yes" in relation to the back, and 34.5 per cent. answered "yes" in relation to the leg.

The patients were asked if they were able to do the same work they had done before the disc protruded. Of those who had undergone simple removal of a protruded disc, 64.4 per cent. answered "yes". When the patients were asked: "Do you think the removal of the protruded disc was worth while?", 93.0 per cent. answered "yes".

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PATHOLOGICAL STUDIES OF INTERVERTEBRAL DISCS *

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The study of pathological material removed at operation on the intervertebral disc has revealed certain lapses in our knowledge of this subject. The relation of the gross appearance of the disc at the time of operation to many obviously pathological microscopic findings was not clear. Furthermore, there existed considerable doubt as to the prognostic significance of these pathological findings. With the above questions in mind, the present study was conducted.

The intervertebral disc is a dynamic structure, subject to considerable stress and strain during ordinary activities, which undergoes definite anatomical changes from the time of birth until senescence[7,8,9,17,18,19,21]. Physiological changes as well as pathological findings in intervertebral discs have been described by many observers[1–9, 11–14, 17–19,21] since the pioneer studies of Schmorl at Dresden reawakened modern interest in this subject. However, microscopic findings in disc tissue removed at operation have been reported only by Deucher and Love; in their excellent monograph, Bradford and Spurling pay but scant attention to this subject. Therefore it seemed expedient to report our findings on a series of specimens which had been removed at operation.

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degeneration of the disc is an early and regular phenomenon of senescence is now generally recognized. The recent studies of Coventry, Ghormley, and Kernohan show that the nucleus pulposus begins to break up as early as the second decade, and in the third decade it already shows signs of wear and tear. There is hardly any structure of the body, not even the tendons, which undergoes senescent changes as early as does the disc.

The greatest amount of degeneration occurs in the fifth and sixth decades, according to Deucher and Love. These changes consist of defibrillation, hyalinization, fissure of the fibrocartilage, defects in the cartilage plate, and erosion of the cartilage with formation of numerous clefts and fissures, which prepare the way for future herniation. The nucleus pulposus undergoes progressive fibrous replacement until it becomes of almost the same consistency as the annulus.

In contrast to the findings in osteoporosis, where the disc balloons out, owing to the lessened resistance of the vertebral body, in the aging spine a thinning of the intervertebral disc is found; and, as a reaction to the loss of disc substance, hypertrophic arthritis appears with the development of spurs and bridges.

The question arises as to the mechanical effect of this degenerative thinning of the disc upon the lumbosacral junction. It is obvious that the disc no longer acts as a firm buffer between the vertebral bodies; the junction has been weakened. Lateral and forward displacement may occur as a shift of the disc takes place, which causes it to protrude in all directions. It may spread under the anterior longitudinal ligament for a certain distance. The protruded material consists chiefly of desiccated nuclear tissue[8].

Since the disc has lost its turgor and its elasticity, this affects the equilibrium which normally obtains between the disc, the longitudinal ligaments of the vertebral column, and the longitudinal and segmental ligaments of the arches. All these now are relaxed, whereas before they were under tension, since the vertebral bodies are no longer forced apart by the disc.

This intrinsic passive equilibrium, which normally makes the spine rigid and resistant to deformation, is now destroyed. Sometimes the relaxation of the intervertebral junction can be demonstrated at operation by moving the spinous processes sideways and against each other. At any rate, a relaxation exists in the structures lying posterior to the disc; the ligamenta flava, the intertransverse ligaments, and the interspinal ligaments are no longer kept at tension. It is for this reason that a degenerated disc can and does produce the inclination to periodic attacks of soft-tissue strain in the lumbosacral junction or above, without necessarily being herniated.

The destruction of the normal equilibrium between the disc and the ligaments affects also the intervertebral articulations. The joint bodies are jammed together because the distending action of the disc is gone. They respond to this by hypertrophic arthritic changes. The intervertebral foramen becomes encroached upon, and root symptoms may appear in the territory of the fourth or fifth lumbar root.

The most intricate diagnostic problem lies in the evaluation of the herniation itself,— the meaning of remissions and of exacerbations in terms of pathological findings. The posterior protrusion of the disc was known to von Luschka in 1858. It was described by Goldthwait in 1911. Calvé and Galland reported it in 1922, and it was finally rediscovered by Schmorl in 1929. It is a common occurrence (according to Beadle, in 15 per cent.), the same as are herniations in the axial direction, which have been so well described by Schmorl. The question is what constitutes a herniation. It is described as a smooth, elongated, or spindle-shaped formation, ranging in size from one-eighth to one-quarter of an inch; and it has a peculiar pathological variation in form, in density, in mass, and in anatomical relationship to the contents of the spinal canal.

Duncan and Hoen distinguish three types of herniation, as found at operation. *These* are the simple herniation, which appears as a round bulge with the consistency of a tennis ball; the already ruptured mass which migrates into the extradural space; and the fibrous

With increasing age, certain changes are apparent in the cartilage plate: It becomes thinner, cellularity diminishes, and cells in various stages of degeneration are found. Microscopic extensions of nuclear material occur with increasing frequency, either within the hyaline cartilage or, through tears, into the spongiosa, with the formation of Schmorl's nodes. Healing may occur in these defects, with invasion by fibroblasts and endothelial buds that originate in the bone marrow. Gross examination may disclose fibrillation or parallel tears in the cartilage[1,16]. Table I shows the incidence of these changes in the forty discs studied.

Annulus Fibrosus

The annulus fibrosus consists of dense fibrous tissue in lamellae, arranged generally in parallel fibers with connecting bands. From ten to twelve lamellae are present in the lumbar region[14], the outer layers being composed of coarser fibers than those close to the nucleus pulposus. The fibers are attached to the elevated bony epiphyseal ring through Sharpey's fibers, which bind together the adjacent vertebral bodies. The inner lamellae are derived from the cartilage plates. Superiorly and inferiorly, a thin layer separates the cartilage plate from the nucleus. Fibroblasts with elongated compressed nuclei are present between the collagen fibers; cartilage cells are also sparsely disposed,—usually singly, but occasionally in clumps. Coventry, Ghormley, and Kernohan point out that increasing clumps of cartilage cells accompany other degenerative changes.

With increasing age, swelling of the lamellae becomes apparent and hyalinization of the fibrils occurs. Schmorl, Beadle, and Saunders and Inman emphasize the appearance of radial and crescentic fissures. Radial fissures occur most frequently in the thoracic region, and are of particular importance, since they may serve as portals for the extrusion of material from the nucleus pulposus into the vertebral canal. A peculiar type of pigmentary deposition may accompany other degenerative changes. The origin of this pigment is obscure; some authors believe it to be derived from old blood[1,2,3]. Fibrosis with vascularization is seen, probably as the result of trauma with resultant healing. The vessels are derived from either the longitudinal ligaments or from the adjacent loose areolar tissue.

In our postmortem material, swelling and hyalinization of lamellae was the most frequent change; scarring with fibrosis and vascularization was found in three cases; fissures, crescentic tears, and pigmentation of the annulus were not observed.

Nucleus Pulposus

The nucleus pulposus is the expanded central portion of the intervertebral disc, surrounded by the annulus fibrosus and merging with it. In regard to the anteroposterior plane, it is disposed posterior to the mid-line. When examined grossly in the fresh state, the nucleus is composed of glistening, whitish translucent material of elastic consistency. When the disc is sectioned sagittally, the nucleus is seen to bulge slightly over the confines of the annulus. Upon immersion in water it has been shown to swell markedly. The water content of the nucleus has been determined at various ages, and a progressive decrease has been found,—from 88 per cent. in the full-term foetus to 69 per cent. at the age of seventy-seven.

Microscopically, the nucleus is composed of an interlacing fine fibrillar structure with a clear stroma, resembling connective-tissue mucin. Three types of cells are seen,—fibroblasts, cartilage cells, singly and in clumps, and notochordal cells. The latter are described as usually occupying the central portion of the nucleus, in clumps, being most prominent in younger discs. These cells were not seen in the cases in this series.

The peripheral portion of the nucleus is increasingly fibrous, the fibers finally blending with those of the annulus fibrosus. Coventry, Ghormley, and Kernohan describe the nucleus as being most distinct from the annulus during the second decade; following this, the line of demarcation becomes decreasingly distinct.

TABLE I

Results After Conservative Treatment of 100 Cases of Low-Back Pain in Which the Procaine Test Was Employed

	Greatly Improved or Cured	Little or No Improvement
Positive Test	58	11
Negative Test	6	25
Totals	64	36

process, which shows phases in which the protrusion is still free and movable and capable of spontaneous reduction; in other phases there is fixation of the protrusion and definite adhesions to nerve trunks. It is still a question as to whether or not an acute traumatic herniation does exist,—that is, one where the sciatic radiation occurs immediately after the trauma and is not preceded by low-back pain.

DIAGNOSTIC IMPLICATIONS

These pathological observations have certain diagnostic implications. First of all, one must prove that a disc lesion exists and, if it does, that it is responsible for the radiation; and next, that it produces other objective, so-called neurological, signs.

For this purpose the students of intervertebral discs have set up a useful diagnostic scheme. It consists of a history which indicates the cause, duration, and continuity of the radiation; a neurological examination, which reveals the so-called neurological signs, including paraesthesiae, numbness, areflexia, and shrinkage; and the so-called orthopaedic signs, which disclose such things as changes in posture, rigidity, and restriction of motion.

All of these signs have been tabulated by many authors, according to their relative frequency. Some are very significant, such as areflexia, while others are less so. The question arises of how much is necessary to make the diagnosis reasonably certain.

In former years, Hyndman, Steindler, and Wolkin agreed not to make a diagnosis of a protruding disc, producing sciatica, unless neurological signs were present. Consequently, almost all patients who were operated upon had protruding discs, and the diagnostic average was well over 90 per cent. Although disc lesions were found where expected, however, they were not always expected when present, and no doubt many of them were missed.

On the other hand, Dandy insisted that every case of persistent sciatica meant a disc lesion. The result was that any patient with persistent sciatica was suspected of having a disc lesion. It is obvious that under this policy all protruding discs were probably found; but, on the other hand, a great many patients were operated upon without a protruded disc being found. It is quite clear that unless a certain "middle-of-the-road" policy is adopted, a satisfactory solution will not be found.

The diagnosis of a protruded disc should be made if neurological signs are present and if the history and other complaints substantiate it. In fact, when a proper history and corresponding physical examination disclose so-called neurological signs, we do not look for a further test for the diagnosis. Visualization serves as corroboration, and also helps in the localization of the abnormal disc, rather than in the diagnosis itself.

In order to improve diagnostic accuracy, two further procedures are used in cases in which the history, or the absence of neurological signs, produces uncertainty.

The novocain test eliminates the diagnosis of a protruded disc in those cases in which the sciatic radiation is purely a reflex phenomenon. These patients show no neurological signs,—that is, no areflexia, no paraesthesia, and no anaesthesia. The test is only applicable if a trigger point exists, because the substance of the test is that the trigger pain and the sciatic pain should completely and simultaneously disappear upon the injection of 1 per cent. procaine. The test, of course, is based upon the fact that the local lesion, on the

TABLE IV

MICROSCOPIC FINDINGS IN 166 SURGICAL CASES (182 DISCS)

Decade	Cartilage Plate		Annulus Fibrosus	Nucleus Pulposus		
	Nuclear Extension	Vascularization	Scarring	Granular Degeneration	Fibroblastic Proliferation	Vascularization
			HERNIATED			
Second						
Third	1		2	5	4	4
Fourth	3	1	13	13	12	10
Fifth	1	1	11	8	15	9
Sixth	1		3	7	7	7
Seventh				2		
Totals	6 (6.5%)	2 (2.1%)	29 (31.5%)	35 (38.0%)	38 (41.3%)	30 (32.6%)
			BULGING			
Second				2	2	2
Third				2	2	2
Fourth	3	1	5	14	3	3
Fifth	1		6	12	5	5
Sixth		1	3	6	3	3
Seventh			1	1		
Totals	4 (6.6%)	2 (3.3%)	15 (25%)	37 (61.6%)	15 (25%)	15 (25%)
			SOFTENED			
Second			1	2	1	1
Third			1	5		
Fourth	1	2	2	4	3	1
Fifth	1	1	2	3	1	1
Sixth			1	3	1	1
Seventh				1		
Totals	2 (6.6%)	3 (10%)	7 (23.3%)	18 (60%)	6 (20%)	4 (13.3%)

sixty-six. The age distribution by decades is shown in Table II. Ninety-seven per cent. of the discs removed were from the fourth lumbar level (46 per cent.) or the lumbosacral level (51 per cent.). The remainder included the third lumbar disc. The fusion operation was not performed on any of the patients in this group.

For purposes of better correlation between laboratory studies and clinical findings at the time of operation, all of the cases were taken from the service of the same surgeon (J. Albert Key, M.D.). At the time of operation the lesions were described as "herniated", "bulging", or "softened". The latter group includes the concealed disc described by Dandy. When the nucleus was herniated, curettage of the remaining disc was not performed routinely; but when it was bulging or softened, curettage was always carried out. The gross material varied accordingly. When the herniated nucleus was removed in one piece, the tissue consisted of a central mass of firm, white, fibrocartilaginous tissue with multiple nodular excrescences at the periphery, and varied in size from 1 to 5 centimeters in greatest dimension. This tissue in all of the cases consisted of nucleus pulposus with adherent lamellae of the annulus fibrosus. When the disc was curetted, the fragments were entirely nondescript and irregular. In 60 per cent. of the entire group, fragments of hyaline cartilage plate were identified. Fibers of annulus fibrosus predominated in many of the curetted specimens.

Microscopic abnormalities were found in all three portions of the disc, the changes being similar to those found in the control group. The major pathological changes are summarized in Table III.

where the diagnosis is certain on the grounds of the clinical examination or where the tests and trial treatments have failed, the operation is indicated. We prefer, first, to be conservative in the laminectomy,—that is, to remove as little of the arches as possible. Second, the laminectomy should be followed by fusion of the spine by one of the recognized methods, even though it entails a longer period of recumbency. Recently, we have used the so-called "clothespin" method of Bosworth with gratifying results.

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analysis of Deucher and Love's figures, it is seen that oedema was found chiefly in the younger age groups,—those in which water content is highest. We cannot agree with their hypothesis that recurring oedema may account in part for the intermittency of pain in these patients.

Table V shows the major findings in relation to the appearance of the disc at the time of operation. Of the 182 discs, 92 were described as herniated, 60 were bulging, and 30 were considered to be softened. These groups are not sufficiently large to allow definite conclusions to be drawn, but it would appear that very little correlation can be established between the gross and microscopic findings. It was hoped that some marked difference could be found in the softened or concealed group; but examination of Table IV will show that consistent changes were not found in this group.

FOLLOW-UP STUDIES

A routine questionnaire, designed to secure information concerning operative results, residual symptoms, and possible relation to compensation, was submitted to each patient. The form was made as simple as possible and required, at most, a short answer; many patients disregarded the form completely, however, and sent a letter in its place. Unfortunately, the response was incomplete.

In interpreting the answers, an effort was made to be as objectively critical as possible. It may be that a less severe interpretation might be possible in several cases. The results are summarized in Table V. It was apparent that compensation was of no importance in this group, for the surgeon preferred not to handle compensation cases. As one would expect, the best over-all results were obtained in those cases in which definite herniation of the nucleus pulposus was found.

The entire group shows that 87 per cent. of the patients were entirely or partially relieved of symptoms. All of these patients were able to return to a fairly normal life; any patient unable to make a living was considered not improved. This percentage would appear to be encouraging, and compares favorably with results obtained by other well-established surgical procedures.

No explanation is offered for the patients having residual pain with sciatic radiation. This number appears to be rather large, particularly in the "herniated" group.

No correlation could be found between the clinical results and the microscopic findings. In eight of the fourteen unimproved patients, marked pathological changes were found during microscopic examination of disc tissue. This also was a result to be anticipated, if the clinical symptoms are solely the result of pressure on nerve roots.

CONCLUSIONS

1. The examination of forty lumbosacral intervertebral discs removed from cadavera of different age groups revealed certain changes in the cartilage plate, the annulus fibrosus, and the nucleus pulposus which must be considered physiological,—either the result of repeated minute traumatic episodes or of aging.

2. In comparing the findings in the cadavera with those in 182 intervertebral discs partially removed at operation, it was apparent that the difference was in number rather than kind. The principal changes encountered consisted of extensions of the tissue of the nucleus pulposus into the cartilaginous plate; vascularization of this defect; scarring with vascularization of the annulus fibrosus and nucleus pulposus; and granular degeneration, considered the result of desiccation, in the nucleus pulposus.

3. At the time of operation the disc was described as herniated, bulging, or softened. No significant microscopic differences were found in the three groups.

4. Follow-up studies on the surgical cases show good results in 86.7 per cent. The best results were achieved in those cases in which the disc was described at operation as herniated. No relation appears to exist between microscopic findings and end results.

The nucleus pulposus is a semifluid substance, with a water content of over 80 per cent. It is confined between the cartilaginous plates and the slightly elastic annulus fibrosus. Because of the high water content in the nucleus pulposus, it is incompressible and follows Pascal's law. Forces applied to the nucleus are transmitted throughout the nuclear material, and the forces exerted upon the cartilaginous plates are thus equalized.

It should be emphasized that the pressures exercised, through the vertebral bodies, onto the nucleus pulposus are resisted by the inherent elasticity of the annulus fibrosus and other related ligaments of the spine, such as the ligamenta flava. Upon these ligamentous structures the entire elasticity and resiliency of the spine depends. The nucleus pulposus has often been described as an elastic cushion, absorbing shocks to the spine. Such a conception is entirely erroneous, since the nucleus consists largely of water, which is incompressible and possesses no elasticity whatsoever. The elasticity of the spine is therefore derived, not from the static structures such as the nucleus pulposus, but from the elastic resistance which the ligamentous structures exercise against deformation of the fluid content of the disc. Therefore, the critical feature in the disturbance of spinal mechanics and in the production of pain is the effect on the ligamentous structures, caused by the loss of water or nuclear substance following injury or degeneration.

The nucleus pulposus is confined under considerable pressure[21,22]. Even in the completely supine position, the total pressure within the disc which tends to separate the adjacent vertebrae is about thirty pounds in the lumbar area. During motions of the spine, this pressure may rise to astounding values. The retention of water within the nucleus and the development of pressures sufficient to withstand the forces applied to them can only be achieved through osmotic pressure. The substance of the nucleus should be looked upon as the impermeable solute which draws water through the cartilaginous plates from the highly vascular spongiosa of the vertebral body. Therein, perhaps, lies the explanation for the almost complete suppression of the secondary center of ossification of the vertebral body; this brings the cartilaginous plates into closer contact with the nucleus, for they must act during life as the semipermeable membranes through which water is continually diffused to the avascular nuclear material.

Should the pressure tending to approximate two vertebrae exceed the osmotic pressure developed within the nucleus pulposus, fluid would be driven from the disc through the cartilaginous plate into the spongiosa of the vertebra. Should the reverse hold true, the higher osmotic pressure would draw water from the spongiosa into the interior of the intervertebral disc. That such diffusion does occur is indicated by DePuky's studies of diurnal variation in height. An individual, getting up in the morning, is taller than when he goes to bed at night. During the activities of the day, the forces acting on the spine may be greater than the osmotic pressure within the disc, and fluid is driven from it. This diurnal variation in height is approximately three-quarters of an inch in males and one-half inch in females.

It is obvious that, should the cartilaginous plate become less permeable, this free exchange of water would be suppressed. This occurs with increasing age, and results in a progressive desiccation of the nucleus[23,33].

The delicate mechanism of water balance can be destroyed through even minute punctures in the cartilaginous plates, which interrupt its function as a semipermeable membrane. Similarly, small rents in the annulus fibrosus, permitting escape of nuclear material, will immediately reduce the fluid pressure. Numerous authors have proved this experimentally[5,13,15,26,30], and clinical confirmation, in man, of these experimental findings is found in cases of injury of the intervertebral disc even by the minute openings resulting from damage during spinal punctures[2,8,16,18,20,28].

The resiliency of the spine and the motions permitted to it are not due to any elastic turgor of the nucleus, but to the elasticity of the ligamentous structures. The first and most important of these is the annulus fibrosus. The annulus fibrosus consists essentially of concentric fibers, passing in oblique and spiral arrangement from one vertebral body to

AN ANALYSIS AND DIFFERENTIATION OF LOW-BACK PAIN IN RELATION TO THE DISC FACTOR *

BY ARTHUR STEINDLER, M.D., IOWA CITY, IOWA

Three problems of a pathological nature have been selected, on the grounds that they are essentially related to the diagnosis of the herniation or degeneration of the intervertebral disc.

PATHOLOGICAL OBSERVATIONS

The first question is whether or not it can be assumed that the disc is a producer of local pain, in the sense that the pain can originate in the tissue of the disc itself. The structures concerned are the disc and the long posterior ligament. Their endowment with sensory nerves must be considered.

In recent studies, Roofe demonstrated nerve endings in large numbers in the posterior longitudinal ligament. He also found nerves in the annulus fibrosus, but could not determine their origin or course. Jung and Brunschwig could not observe nerve fibers in the disc itself. Ehrenhaft found evidence that the annulus fibrosus has some nerve fibers, which until recent years had been denied.

In the anterior longitudinal ligament, however, the nerve fibers are readily found, which is not surprising, since this ligament might be expected to impart information on position. The nerve fibers beneath the anterior ligament give off fine branches, which accompany the periosteal vessels entering the cartilaginous substance of the disc.

The sensory innervation of the posterior portion of the spinal column is largely furnished by the nervus sinuvertebralis of von Luschka, first described by him in 1858. This nerve is a recurrent branch of the spinal nerve, coming off just distally to the ganglion of the posterior root. As it separates from the main trunk, it reaches the vertebral foramen and supplies all ligamentous structures, the capsular apparatus, the posterior longitudinal ligament, and the periosteum. It is also said to contain sympathetic postganglionic fibers for the blood vessels.

Since it is a lumbar nerve branch, the pain caused by it should be local—perhaps with some spread over the gluteal region or possibly the upper aspect of the thigh—but it cannot cause sciatic radiation. The conclusion is that, with the disc intact, very few if any pain symptoms may be expected to originate in the disc itself. That the disc acts as a joint and that it must be endowed with proprioceptive organs is not a valid argument, because the proprioreception does not come from the joint bodies any more than it comes from the cartilages of the knee. It comes from the synovial membrane, the capsular reinforcement, and the ligaments about the joint; it also originates in the muscles and their periosteal attachments. The structures in which distress is frequently produced on forward flexion, for instance, are in sequence as follows: the ligamentum interspinalium, intercrurale, or flavum, the intertransverse ligament, the capsular reinforcement, and, last, the supraspinal ligaments. The muscles are the sacrospinalis, the quadratus lumborum, and the deeper back muscles. By their anatomical arrangement, these structures are the first to receive stress, and there is no reason why they should not also be the first to produce sensory symptoms.

The second problem concerns the effect of degeneration and thinning of the disc, irrespective of herniation, on local pain.

When the disc degenerates and loses its height, a change occurs in the relationship, not only of the vertebral bodies, but also of the arches and the intervertebral joints. That

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"sclerotogenous" pain and the region to which it characteristically radiates as the sclerotome, in contrast to the skin areas known as the dermatome.

The failure to appreciate the distinction between dermatomal and sclerotomal distribution of referred pain has been responsible for several attempts in recent years to modify strangely the dermatomal charts derived from the unimpeachable experimental evidence of Sherrington and Foerster.

There may be a subjective feeling of uselessness in the extremity afflicted. The extent of the radiation varies directly with the intensity of the original stimulus, and is usually appreciated as extending continuously from the point of stimulation to the most distal point of radiation.

That the periarticular connective tissues are exquisitely tender is not often appreciated, nor is the fact that radiation of deep pain is to be expected with irritation of these structures, and may occur without the direct stimulation of a peripheral nerve or nerve root.

Unfortunately, the anatomical studies of the nerve supply to ligamentous structures have lagged behind the experimental findings. However, the annulus fibrosus has been shown to possess a rich nerve supply, mostly of amyelinated fibers[24,32]. It is permissible to assume that these are sensory fibers, inasmuch as the intervertebral disc is avascular; and these fibers are, therefore, probably not sympathetic in origin.

These physiological and anatomical observations would lead one to expect that an irritative lesion or injury to the periarticular structures of the spine would result in deep, aching pain, and this pain would normally radiate distally to a varying degree, depending upon the initial stimulus. This radiation of pain will accompany, in varying degree, any injury to these structures without direct involvement of the nerve root. How distinctive is the distribution of pain arising from sclerotogenous sources is illustrated by the following two instances: First, it is well known that, in lesions of the sixth cervical disc, patients may complain of deep but intense pain over the precordium. Such a distribution has no relationship to that of the associated spinal nerve, but may be reproduced experimentally by stimulation of the ligaments in the region of the fifth, sixth, or seventh cervical segments. The second instance, among many, is that of a patient suffering from low-back pain and sciatica and diagnosed as having a possible herniation of the disc; roentgenography disclosed a tumor in the ilium. This tumor, on biopsy, proved to be a metastatic hypernephroma. The expanding tumor bore no relationship whatever to the sciatic nerve or any of its components, yet the radiation was characteristic of that often encountered in injuries of the disc, and corresponded to the known sclerotomal area associated with the periosteum of the iliac bone.

There is now abundant experimental evidence to support the contention that distortion of the annulus fibrosus and related ligamentous structures of the neighboring joints, consequent upon loss of nuclear substance or nuclear degeneration, is in itself the source of pain of a characteristic type which, depending upon the level involved, may be referred to fairly specific areas of the body. Therefore, with this conception of the mechanism, it is easy to understand the clinical case in which an injury to the lower part of the back has been sustained, and in which the patient complains, not only of local pain, but of discomfort, radiating down the posterior aspect of the thigh over the involved sclerotome. This radiation is misleadingly called sciatica, with the notion that pressure or irritation directly involves the nerve roots. The picture is complicated by the fact that injuries to the ligamentous structures about the spine may involve the spinal root, because of its close relationship to these structures.

The fibers of the cauda equina, which separate to form each lumbar nerve, leave the dural sac at approximately the level of the intervertebral disc of the segment immediately above. The nerves cannot truly be said to penetrate the dura, but carry with them a covering of dura which blends imperceptibly with the epineurium more distally. This contribution of the dura to the connective tissue of the nerve root increases its diameter in

fixation of the mass to nerve elements in the spinal canal. Hyndman speaks of the herniating and the herniated discs. It is obvious that we are dealing with different phases of the same process. The important part seems to be that the herniating disc shows definite oedematous swelling of the protruding portion. In their description of pathological findings, based upon 100 specimens, Deucher and Love emphasized the fact that some oedema was present in the majority of cases, and in 20 per cent. of them it was marked. It is quite probable that the oedema had something to do with the exacerbation of radiating pain. It might explain why, in many cases in which repeated painful attacks occur over a period of years, relatively small protrusions are found at operation. The ability of the nucleus to swell should not be underestimated, since it can increase to many times its original size. In old persons the capacity of the nucleus to swell is, of course, markedly decreased owing to degeneration; and, therefore, the protrusion of the disc does not always produce symptoms. Dandy speaks of a concealed disc, which he found in 28 per cent. of his series of 37 cases,—that is, the disc bulged out so slightly that it never could be disclosed by visualization, either with iodized oil or air.

The variability and instability of the disc and its changing relationship to nerve roots have given substance to conservative methods of treatment, which otherwise might be hard to justify. We know that the body assumes a tilt, or so-called sciatic scoliosis, as a defense position. If the disc lies lateral to the root, the tilt is to the opposite side. The herniated portion is then made to draw into the widened space between the vertebral bodies.

Similarly, a centrally located disc may be drawn into this space when the patient bends forward. This calls to mind the therapeutic principle of Putti. He immobilized these patients with sciatic scoliosis "as is",—that is, without ever changing the position. He knew that it was a position of relief, which must be respected, and which would disappear automatically as soon as the pain and the accompanying reflex contraction were controlled. Obviously this can only apply to the mobile disc. Scott and Young emphasized the differentiation of the fixed and movable discs. The fixed disc should always be removed, because it gives persistent sciatic symptoms. The mobile disc is one which protrudes into the spinal canal when the patient is in the upright position, but returns to its normal position with hyperflexion of the thighs and back; and it herniates again to its maximum when the patient's back is hyperextended. This variation in protrusion was definitely demonstrated by Scott and Young, who took roentgenograms with the patients in different positions, after the injection of air. We can well understand the reason why conservative treatment of sciatic pain can be carried out successfully, on these grounds. For instance, Kuhns reported his results in 1,000 cases of low-back pain with sciatic radiation, treated conservatively by such methods as bed rest, support, and physiotherapy. He obtained good results in 79 per cent. of the cases. This is not surprising when we consider that some of these cases were probably of the reflex type (a condition which will be referred to later), and many of the patients must have had protruded discs which receded after proper immobilization in a suitable position.

Thus the three pathological facts believed to be of significance are these:

1. The disc has few, if any, sensory fibers, while the neighboring capsular ligamentous structures are richly endowed with sensory elements, and all the sensory endowment comes to these fibers from branches of the posterior primary division.

2. During the process of degeneration of the disc, and as a result of it, the equilibrium between the disc and the longitudinal ligamentous system is destroyed, and this disturbance is only incompletely compensated for by arthritic ledges and buttresses. The result is that the junction between the vertebral bodies is loosened; and stress is placed, therefore, upon the supporting ligamentous and muscular system.

3. In the presence of this disturbed equilibrium, the disintegration of the disc proceeds, leading finally to herniation into the spinal canal. Herniation is an evolutionary

intact skin[31] causes paraesthesiae in the area supplied by the nerve, but there is no subjective sensation of pain. Electrical stimulation of the exposed human nerve elicits sensations analogous to touch and "fast" pain only[9].

From these experimental findings and clinical observations, one would anticipate that rapidly applied pressure, sufficient to evoke mechanical stimulation, will first produce paraesthesiae, due to stimulation of the proprioceptive, touch, and "fast" pain fibers. If the pressure is applied slowly so as merely to cause blocking of the fibers by their physiological interruption, the motor, proprioceptive, and touch fibers will be affected first, followed by those of "slow" pain and temperature.

In the clinical cases of herniation of the intervertebral disc with apparent pressure upon the nerve root, this is not the common sequence of events. The first symptom to appear is usually pain. This pain is a characteristic deep ache, which usually radiates down the extremity in a more or less continuous path corresponding to the affected sclerotome, and is of the order of "slow" pain. Later, evidence of nerve-root compression may or may not appear. The onset of compression is indicated by the appearance of clinical findings, following the anticipated sequence, supported by experimental investigations. Thus, there is loss of vibratory sense and tactile discrimination, hypaesthesia and hypalgesia over the area supplied by the related dermatome, muscle weakness, and reflex changes.

The predominant symptom of pain, appearing early, is as yet unexplained. As far as we are aware, there is no experimental evidence to indicate that pressure alone upon the nerve root initiates pain of this characteristic type. It may be suggested that the chemical changes associated with inflammation alter the threshold values of the intact nerve at the site of the lesion and thereby provoke the onset of pain. This is, however, unproved. Further investigation is certainly necessary before this aspect of the problem is answered, and before we possess sufficient understanding to undertake more precise therapeutic measures. On the other hand, it has been established that noxious stimuli to the ligamentous structures will experimentally produce the deep aching pain which is so characteristic of the early stages of sciatica. With these positive observations, one wonders whether or not the deep pain may be of a referred nature from the ligamentous structures around the spine and the interference of spinal mechanics. Only when nerve-root compression is marked does the course of physical findings follow those anticipated from the experimental work. Until further investigation is carried out, we are justified in using this conception as a working hypothesis in the evaluation of cases of herniated discs.

Consequently, we are led to a division of patients into three general categories:

1. Those with backache and local signs and symptoms of injury to the vertebral ligamentous structures, who present radiating pain, deep in character, extending down one or both extremities. The extent of the radiation is indicative in some measure of the degree of irritation or injury to the ligamentous structures. Patients falling into this category should be considered as suffering from mechanical derangement of the spine, and should be treated by immobilization and support. If the symptoms subside, there is some justification in assuming that the condition has been evaluated correctly.

2. The second group includes those cases in which the symptoms are identical with those found in the first group, but, in addition, reveal definite evidence of nerve-root compression. In this group, pain is relatively as prominent a phenomenon as is the evidence of compression. Here it should be borne in mind that the influence of pressure will interrupt nerve conductivity in a precise sequential fashion: The larger fibers conveying proprioceptive sensation and motor impulses will be affected first; those of pressure, touch, and "fast" pain, next; and finally, the sense of temperature and deep pain will be lost. The presence in these cases of positive objective evidence of nerve-root compression leaves no doubt that treatment should be directed towards the relief of pressure, to prevent permanent damage to the affected nerve root. It should be realized, however, that the mere removal of the herniated or displaced disc will not affect the factors associated with liga-

one hand, and the sciatic area, on the other hand, are anatomically entirely and completely independent of each other as far as nerve supply is concerned, since the former is supplied entirely by the posterior primary division and the latter by the anterior primary division. The result of this test must be striking in order to be evaluated. There is no middle ground. The interpretation must be very rigid. The patient must volunteer the information that pain has now completely disappeared—both locally and by radiation—and the surgeon must verify this by the disappearance of the leg-raising sign (Table I).

When the test is positive, however, it furnishes absolute proof that the pain is of reflex character and not referred, and that, therefore, a disc lesion is not present and no operation is necessary.

We do not know what percentage of these cases of low-back strain with sciatic radiation are on a purely reflex basis, but that they do exist has been demonstrated on numerous occasions. We do not always find a trigger point as well as radiation, although both are necessary to carry out the test. Consequently, one may say that there are more cases of reflex sciatic pain in existence than can be proved by that test. Without the test, patients undoubtedly will be operated upon in whom no disc lesion is found.

We are told, furthermore, that in many of these instances in which a protruded disc is not found, the ligamentum flavum is hypertrophied. There is no reason why this ligament should not become hypertrophied. As Grant puts it, taking his cue from Fick, these ligaments are "sparers" of muscles and assist in the recovery of the erect posture after bending, and they are exceptionally strong in the lumbar region. There is no reason why they should not undergo compensatory hypertrophy to make up for the instability produced by the degenerating or herniating intervertebral disc, especially since these ligaments continue their course into the capsular apparatus of the intervertebral joint, which they substantially reinforce[13]. This brings up the last point of discussion,—namely, of whether or not the lumbosacral spine should be fused after the removal of the disc.

Fusion should be done in all cases in which instability of the lumbosacral junction has manifested itself by prolonged and repeated attacks of backache. This is a strictly local disturbance, and it is not taken care of by the removal of the disc. These two conditions may be related, but only in so far as the degeneration of the disc may be responsible both for the instability of the lumbosacral junction and for the herniation which causes the referred sciatic pain. Barr and Mixter stated, on the basis of ninety-nine cases, that, with laminectomy and disc removal alone, the relief of back symptoms was not so satisfactory as was the relief of the radiation. Seventy-three per cent. of the patients in whom the spine had been fused had relief of the back symptoms, and only 52 per cent. of the patients without fusion had no further back symptoms. It does not make much difference if the removal of the disc is carried out with little or no removal of the lamina, since the instability of the spine with attendant attacks of backache existed before operation and was not caused by this procedure.

Similarly, Ghormley, Love, and Young, reporting on seventy-seven patients with protruded discs who had the combined operation of laminectomy and fusion, found the results good in 64 per cent., fair in 25 per cent., and poor in only 11 per cent.

Of forty-eight cases of ruptured, herniated intervertebral disc which were proved at operation in this Clinic, the following results were obtained in thirty-one:

Twenty-three of the group had laminectomy alone and, of these, complete relief was obtained in fourteen cases, or 60 per cent.

Partial relief (that is, residual back pain) was found in nine cases, or 40 per cent.

In contrast, of eight cases in which laminectomy was followed by fusion, complete relief was obtained in seven cases, or 87.5 per cent., and residual backache occurred in one case, or 12.5 per cent.

On the basis of the pathological findings, we are able to conclude that the best policy would be to initiate a conservative trial treatment in all doubtful cases. On the other hand

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DISCUSSION

DR. WILLIAM JASON MIXTER, BOSTON, MASSACHUSETTS: It seems to me that one of the most important things to consider this evening is the pathology of the disc, as exposed at operation. We must consider the questions of an injury to the ligamentous structures, the tearing of the disc itself and of the posterior longitudinal ligament, and the stretching of the posterior ligament. There is also the question of compression of the nerve roots. I have not felt that I had demonstrated satisfactorily to my own mind a ruptured intervertebral disc unless I have proved compression of the overlying nerve roots.

Then comes the question of fusion or non-fusion in the treatment of these cases. Most of us who are treating these cases do practically the same operation as regards getting out loose tissue after the disc has been exposed, but in the matter of fusion or non-fusion there is a considerable difference of opinion. One of the important things that has not been spoken of this evening is the question of the mortality and morbidity of the combined operation, as compared with the operative procedure for removal of the torn disc. The mortality at the Massachusetts General Hospital has been small; I cannot tell exactly the number of patients who have died, but I think that all of the patients who have died within the last ten years have had the combined operation, and I think that all of the patients died primarily of pulmonary embolism. If an operative procedure can be devised which will give satisfactory fusion as well as satisfactory removal of the ruptured disc fragments, without undue risk to the patient and without undue lengthening of the convalescent period, then I will concur with the idea of fusion as part of the primary operation. Before coming to that conclusion, however, we should know how many patients who have residual symptoms consider themselves sufficiently disabled so that they would accept a second operation,—namely, a fusion. I think that the number is pretty small. We may be able to get more information at the Massachusetts General Hospital after studying the whole series of cases, which has not been done. I personally am not making the study of the cases at the Massachusetts General Hospital, but am accepting the results as given by others. That is a very satisfactory way for a surgeon to have his results evaluated, because there can be no bias.

One point has not been stressed in the treatment of intervertebral lesions. In most of these patients who are operated upon primarily for pain, the operation is definitely one of election, and of the patient's choice. The patient has to make a decision, on the basis of the pain he is suffering, as to whether he is willing to continue with the pain—either a steady pain or attacks and remissions of pain—or whether he wants to have something done about it. The operation should not be urged upon the patient. An operation of this sort should be done for its psychological result on the patient while he is having pain, and not during a remission. Motor weakness, however, should be considered a definite emergency and the patient should be operated upon at once. Patients who have foot-drop which has been present for some time and particularly those who have a transverse lesion of the cauda equina which has continued for a considerable period should be studied as soon as possible, because, if the motor weakness is

ANATOMICOPHYSIOLOGICAL ASPECTS OF INJURIES TO THE INTERVERTEBRAL DISC *

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INTRODUCTION

Herniation of the nucleus pulposus, or protrusion of the disc, is now firmly established as a pathological mechanism associated with low-back pain and sciatica. Despite initial enthusiasm, we have little doubt that the majority will agree that the treatment of many of these cases by laminectomy and nerve-root decompression has been disappointing. There is a growing realization that many features of the syndrome are difficult to understand. We believe that a re-examination of certain fundamental anatomicophysiological principles may help to clarify the situation and serve to evaluate better the clinical findings and direct the choice of treatment.

At the very outset, it should be understood that the intervertebral disc is essentially and primarily a part of the functional mechanism of the spinal column and, further, that any relationship which the disc bears to the spinal cord and its roots is purely secondary and, so to speak, fortuitous. Destroy the disc and you destroy, in some degree, spinal mechanics. Therefore, in disc derangement we are dealing with a dual problem,—first, deranged spinal mechanics, and, second, the effects of spinal-nerve irritation and compression. The crucial feature in the symptomatology of both is the presence of pain; but pain, being a subjective phenomenon, is, unless accompanied by objective neurological findings, difficult of interpretation and, therefore, may cause endless confusion. Too often we are compelled in low-back syndromes to rely on the sole subjective reaction of the patient, always unsatisfactory, as a guide to definite and rational therapy; or we must await the appearance of objective signs. Herein lies a great part of the difficulties in interpretation and choice of treatment.

We shall, therefore, consider the intervertebral disc in relation to the maintenance of spinal mechanics and the effects of its loss, as well as the anatomical relationships of the spinal nerve and what is known of its physiological response to pressure and irritation. From these, we believe it possible to clarify some features in the clinical management of the affected individual.

THE INTERVERTEBRAL DISC

The general construction of the intervertebral disc is sufficiently well known not to require any detailed discussion. It consists essentially of three parts: the annulus fibrosus, the nucleus pulposus, and the cartilaginous plates.

The cartilaginous plates cover the bony surfaces of the opposed vertebral bodies and, in part, function during growth as epiphyseal cartilages. In man the secondary center of ossification is extremely limited, and the epiphysis of the vertebra does not develop to the extent found in other mammals and in most primates. In man the epiphysis is merely a peripheral ring of bone, so that the cartilaginous plates bear a direct relationship to the other components of the intervertebral discs and are not separated from them by bony plates. This is surprising, inasmuch as man is the only mammal which requires that forces be borne in a vertical direction upon the opposed surfaces of the vertebral bodies; and these bodies are not protected by bony reinforcing plates, as in other animals. Perhaps the explanation is found in the physiology of the nucleus pulposus.

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shift in the lateral articulations in the lower three lumbar vertebrae and nearly always more pronounced at the fifth lumbar". Dr. Dandy thus reverted to the antiquated theory of spondylolisthesis, advanced by Neugebauer in 1892, before discovery of the roentgen ray, completely ignoring the true explanation of this displacement, as discussed voluminously in the medical literature for more than twenty years.

While we have on the screen the roentgenogram of a severe case of spondylolisthesis, may I read the five conclusions reached by Dr. Dandy in his discussion of the treatment of spondylolisthesis (published in the *Journal of the American Medical Association,* **127**: 137–139, 1945), not one of which can be substantiated:

"1. Subjectively and objectively, spondylolisthesis is precisely like defective intervertebral disks. Only the x-ray differentiated the two conditions.

"2. . . . it is my opinion that spondylolisthesis and defective disks are really identical in origin and the treatment is the same; i.e., complete removal of the disks.

"3. In at least 90 per cent and probably all of the cases there are two or three disks (including the one at the site of the spondylolisthesis) causing the backache and sciatica, and a cure depends on the recognition and treatment of all the affected disks. The disk at the site of the spondylolisthesis causes no more and, on the whole, less symptoms than the other disks.

"4. A cure results when the disks are completely removed. The end result of removal of the disks is fusion of the opposing vertebrae and therefore stabilization of the spine. This obviates the necessity of fusion by bone grafts to the spine.

"5. Spinal fusions by grafts are never indicated either for spondylolisthesis or for defective intervertebral disks. Their continued use means that the disks have been improperly recognized or treated, or both."

A paper published in the *Journal of the American Medical Association* is read by the great majority of practising physicians in the United States, and reaches the libraries in most nations of the world. When such a paper is written by a man of international reputation in his field, the statements made therein are accepted by the readers as true. For these reasons, I believe that Dr. Dandy's paper should not go unchallenged. I have the greatest respect for Dr. Dandy's contributions to neurosurgery, but am convinced that his discussion of spondylolisthesis is based upon a disproved theory of the etiology of that condition. It is difficult to consider seriously any part of a discussion which is based upon so blatant a misconception of its subject.

DR. BARNES WOODHALL*, DURHAM, NORTH CAROLINA:

A. SENSORY PATTERNS IN THE LOCALIZATION OF DISC LESIONS

It is apparent from the discussions that have been presented this evening that the diagnosis of a classical instance of herniated nucleus pulposus depends upon a consideration of several supplementary studies. The statement that any patient with low-back pain and sciatica in all probability has a disc lesion is an important one simply because it directs attention to this possibility, but the statement alone can scarcely be called an accurate diagnosis. Neurological changes, if present, can be considered as one part of the patient's reaction to a disc protrusion, and the preoperative sensory component of the neurological examination illustrates well its value and its shortcomings in the general diagnostic appraisal.

The advantages which the examiner may hope to gain from a preoperative survey of the status of peripheral sensibility in patients with classical disc protrusions may be listed as follows:

1. A knowledge of the incidence of significant sensory changes in this syndrome.
2. A knowledge of what constitutes a significant sensory change in terms of localization and specificity of sensory defect.
3. Some aid in the academic pursuit of defining more closely the peripheral sensory dermatomes in man.

The examination for peripheral sensory changes is required in only a few patients to define the value and limitations of this particular phase of disc diagnosis. Such a survey, conducted in 100 consecutive patients with unequivocal protruded discs removed at subsequent operations, showed that forty of these patients during the period of preoperative study possessed no defect in the common sensory modalities of pain, light touch, heat and cold, or sense of position. In forty-two, sensory changes existed that were considered of value in localizing the interspace where disc protrusion had occurred; and in the remaining eighteen cases, the sensory findings were either spotty in distribution over peripheral dermatomes or existed as false localizing signs. The exact distribution of the cases is shown in Table I.

There is no ready explanation for the fact that a significant number of patients with classical ruptured discs fail to show evidence of preoperative sensory defects. It is obvious that such examinations are conducted over only a brief time phase of the preoperative development of the lesion, and clinical experience indicates that sensory loss and its subjective companion, paraesthesia, may vary during this time period. No adequate correlation with other components of the neurological examination—motor loss and reflex changes—or with the duration and intensity of sciatic pain appears possible. The vari-

* From the Neurosurgical Division of the Duke Hospital and Medical School, Durham.

the next, which receive firm attachment into the substance of the adjacent bone by means of the so-called fibers of Sharpey. Microscopically, the annulus fibrosus is composed of fibrous and elastic lamellae with an occasional cartilaginous cell. Because of the basket-like arrangement of the fibers of the annulus fibrosus, separation of the vertebral bodies is possible, not so much through elasticity of the fibers, as by change in their direction[25,29]. The arrangement leads to constant movement between the fibrous lamellae and eventually to internal wearing of the fibers, followed at length by their partial or complete rupture. Such findings are common pathological observations. Should these annular defects become complete, an extrusion of nuclear material results. Andrae has demonstrated that, in 15 per cent. of all individuals over the age of fifty, herniations of the nucleus through degenerative areas of the annulus fibrosus are found in those portions of the spine which are subject to the greatest movement. As many as five small hernias have been found at one level. However, these hernias are usually insufficient to cause pressure on the spinal root.

With the loss of the internal pressure, the disc naturally collapses. The joint spaces become narrow and the annulus fibrosus bulges laterally. With this lateral bulging, there is a proliferation of new collagenous tissue on the lips of the vertebral bodies. Ossification occurs in this tissue and osteophytes result. The internal edge of an osteophyte marks the extent of the bulging of the annulus. Osteophytes seen in the roentgenograms are direct evidence of a degenerating disc with the loss of internal pressure and a bulging annulus.

It is obvious that the loss of the fluid pressure in the nucleus pulposus leads to grave derangement in the physiology of the disc. Pressures transmitted from the vertebra are no longer distributed equally over the opposed surfaces. The normal tilting motion between the vertebrae is suppressed, but lateral motion is increased and may be of sufficient magnitude to result in rotatory scoliosis of the lumbar spine[17]. The decrease in the vertical height of the intervertebral spaces leads to subluxation of the interarticular zygapophysial joints, in which degenerative changes develop as the result of the abnormal forces acting upon them[19].

LIGAMENTOUS STRAIN

It has been amply shown that the ligamentous structures of the body are the most sensitive to pain[3,10,11,14]. The structures may be stimulated by means of chemical irritants, or by mechanical displacement of the collagenous fibers. The displacement need not be great or forceful to result in a characteristic deep, dull aching pain, which is poorly localized. The pain so elicited is constant in type, but varies in intensity, depending upon the structure stimulated and the severity of the stimulation. The stimulation of the periosteum, of tendons, or of the attachments of the ligaments is accompanied by an extensive radiation of pain, often associated with soreness of the muscles and tenderness over the bony prominences in the region of the radiation. The character of the pain which radiates distally from the site of the point of irritation is similar to that elicited at the point of stimulation, except that it tends to appear somewhat later and at varying intervals of time after the original stimulus. This interval may vary from a minute to several hours. The radiation of pain is characteristically interpreted as being deep within the body, and it has no cutaneous components.

Not only is deep pain periodic and wavelike in character, but it is accompanied, when intense, by vasovagal responses, such as nausea, sweating, fall in blood pressure, and collapse. Herein it differs markedly from the response shown by cutaneous pain. From our experimental experiences, the authors agree with Lewis, who says: "The difference in the quality of pain derived from skin and from deeper structures has led me to suppose it possible that these are separate forms of sensation". In the authors' opinion, there is enough evidence to justify the conception that these two forms of pain are entirely separate and different modalities. Deep pain is derived from, and radiates extensively to, mesodermal elements connected with the skeleton. We have designated this modality as

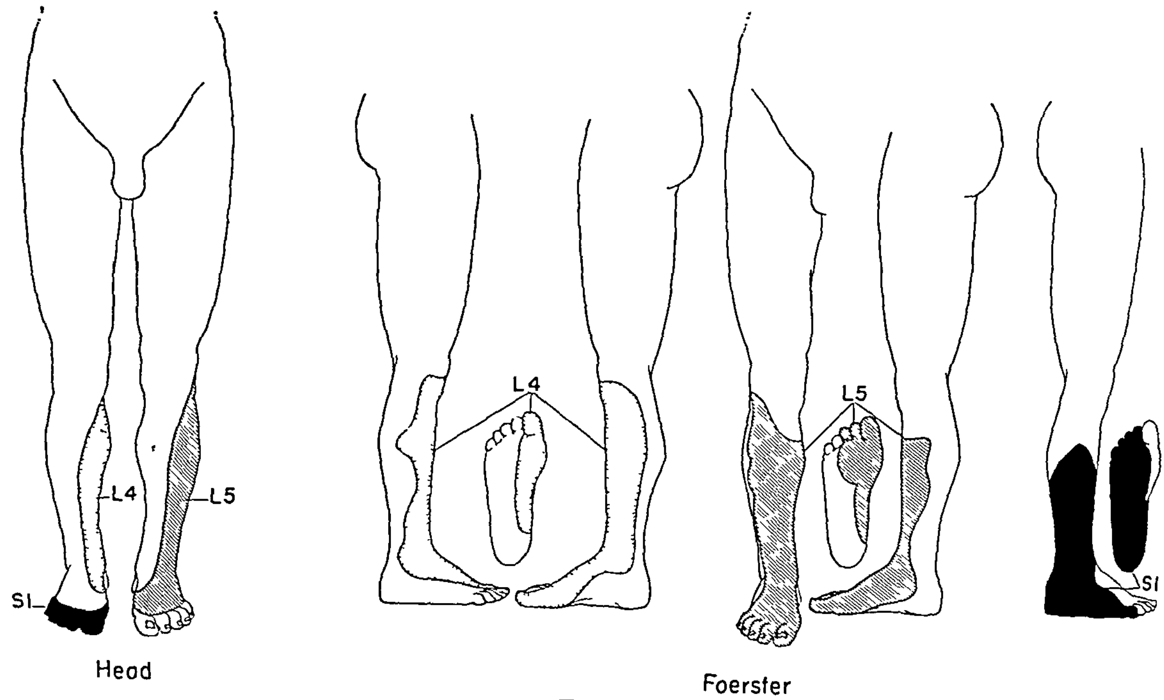

FIG. 3

Unusual sensory dermatomes, described by Head[4] in cases of herpes zoster and as a result of trauma. Considerable overlap of sensory dermatomes of the fourth and fifth lumbar roots may be seen[3]. Compare with Fig. 4.

The remarkable sensory overlap of the dermatomes of the fourth and fifth lumbar vertebrae is denied in Keegan's chart, in which that of the fifth lumbar root is demarcated distally to the second, third, and fourth toes and the dorsum of the foot. The probability of this variant is substantiated by Bradford and Spurling in Figure 34 of their monograph upon disc surgery, and has been noted in scattered individuals in this series. Keegan has reported the fourth lumbar dermatome as involving the large toe and dorsum of the foot, a distribution that he considers characteristic of disc herniation at the third lumbar interspace. In the few disc protrusions at this level, no localizing sensory patterns have been seen in this series; and, in most instances, the diagnosis has been made by myelography.

Foerster did not show an extensive rostral distribution in the sensory dermatomes of the fourth and fifth lumbar and the first sacral roots, although narrow patterns of sensory loss extending from the foot to include the posterior aspect of the leg and thigh are pictured with rhizotomy of the second sacral, and with combined rhizotomies of the first, second, and third sacral. Symmetrical bands of sensory alteration, extending from appropriate areas of the foot to the spine, are pictured for the first time by Keegan. The existence of such unusual and striking sensory patterns appears indisputable in certain cases of disc compression, if these instances are sought for by meticulous examination for diminution in the modality of light pain perception. They are shown most clearly in the sensory patterns considered characteristic of compression of the first sacral sensory root.

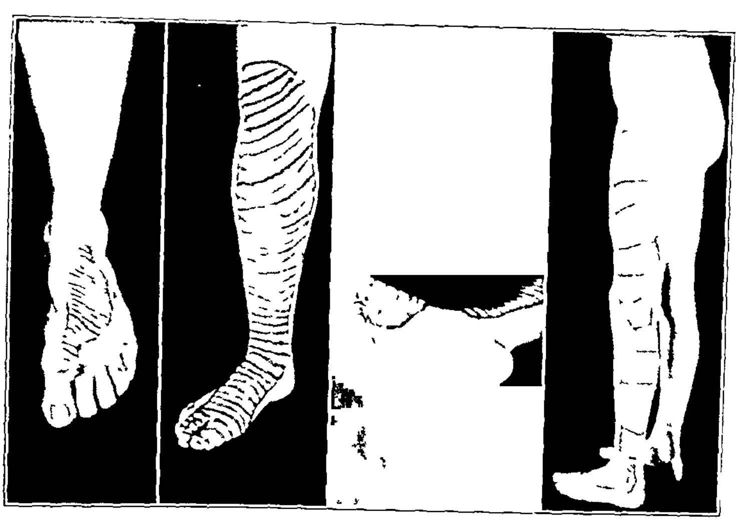

FIG. 4

Sensory patterns with disc protrusions at the fourth lumbar interspace, compressing the fifth lumbar root. Incomplete pattern, pointing toward the great toe and involving dorsum of the foot, is shown at left. Second figure shows characteristic involvement of great toe. Note overlap upon central toes, as compared with previous dermatome charts. The hypalgesia over the calf is, in most instances, situated more laterally.

Third view shows involvement of great toe and palmar surface of foot. Compare with Foerster. At the right is shown another instance of involvement of great toe, dorsum of foot, and lateral aspect of calf. Note rostral extension of the sensory pattern, as described by Keegan.

the foramen to twice the size within the subarachnoid space. Each nerve is firmly attached to the dura, and traction upon the nerve will produce deformation of the dural sac without transmission of the tension to the fibers of the cauda equina. The nerve, as it lies in the intervertebral foramen, is relatively free, being attached to the surrounding skeletal structures only by fine areolar tissue. As the spinal nerve passes through its foramen, it is closely applied to the medial and inferior surface of the pedicle, occupying a smooth groove on this aspect of the pedicle, known as the sulcus nervi spinalis. At the fifth lumbar foramen, and to a lesser extent at the fourth, the sulcus extends obliquely forward into the body of the vertebra. The nerve, in its course through the foramen, occupies only its upper half, the lower half being more or less occluded by the posterior projection of the intervertebral disc and the anterior bulging of the ligamentum flavum. The spinal nerve comes into contact with its own intervertebral disc only at its point of emergence from the intervertebral foramen.

The underlying and fundamental cause of the sciatic pain which occurs in association with herniation of the nucleus pulposus, or a displaced disc, presents many difficulties in its elucidation. A common conception is that such pain is caused solely by pressure on the nerve root. Such a conception cannot be correlated with any of the existing experimental evidence of the effects of nerve pressure. In fact, experimental evidence on nerve compression should lead the clinician to expect a sequence of events far different from that actually found in cases of this nature.

Pain can be divided into two essential types,—namely, "fast" and "slow" pain[14]. "Fast" pain is characterized by being sharp and lancinating, readily localized, appreciated immediately after the application of the stimulus, and so adaptable that immediately after its initiation it is no longer appreciated. In addition, "fast" pain provokes a defense reaction in the subject and is associated with sympathetic hyperactivity. On the other hand, "slow" pain is of a dull, aching character, not readily localized; an interval of time exists between the application of the stimulus and the appreciation of the pain; it tends to spread or radiate extensively; and exhibits little or no tendency toward adaptation. When severe, it is associated with collapse and a tendency of the individual toward withdrawal. Both "fast" and "slow" pain are elicited from the skin; but, as we proceed to the deeper structures, we find that deep pain is most prominent.

The nerve root is composed of a whole spectrum of nerve fibers, ranging in size from 0.5 to 10.0 micra in diameter and with conduction rates varying from 0.6 to 90 meters per second[7]. While a precise correlation cannot be made between the function of a nerve and its size, because of overlap between the various groups, still the evidence would indicate that, in general, the larger fibers belong to the proprioceptive and motor systems and the smaller fibers subserve skin sensations. Among the latter, touch, pressure, and "fast" pain belong to the larger group; while temperature sense and "slow" pain belong to the smaller fibers.

The reaction of the various fibers to mechanical, electrical, and chemical stimulation or to the blocking effects by pressure and asphyxia are quite different. The large myelinated fibers have a low threshold to mechanical and electrical stimulation. They are also the first to be blocked by pressure and asphyxia. On the other hand, the small fibers are the most resistent to blocking by pressure and asphyxia, but are the most susceptible to cocainization and chemical stimulation. These careful experimental studies are borne out in clinical application where uncomplicated factors are at work. It is common experience that sitting on the sciatic nerve causes the foot to go to sleep. The first fibers to be blocked are those of touch, the proprioceptive sense, and the motor system. When the leg begins to awaken, the subject experiences paraesthesiae of tingling, but at no time is there a feeling of pain or ache in the extremity. A cast applied too tightly over the peroneal nerve may lead to loss of touch and proprioceptive sensation, together with muscle power, but pain is usually absent. Electrical or mechanical stimulation of the peripheral nerves through

TABLE II

Herniated Nucleus Pulposus

(Status as of About August 1, 1944, of Patients Admitted During 1943)

Operations Performed During 1943	Total Cases in Sample	Still in Service August 1, 1944	Discharged up to August 1, 1944	
			Number	Per Cent.
Enlisted Personnel				
None	328	72	256	78
Excision of herniated nucleus pulposus (including laminectomy)	126	87	39	31
Miscellaneous or unknown	29	7	22	76
Total cases among enlisted personnel	483	166	317	66
Officers				
Patients operated upon	32	32	0	0
Total cases among officers	59	50	9	15
Total cases (enlisted men and officers)	542			

diagnostic and localizing value. The scarcity of protrusions at the third lumbar interspace makes analysis difficult, and the few cases observed showed no characteristic alterations. Protrusion of the disc at the fourth lumbar interspace, involving the fifth lumbar root, usually gives evidence of compression of this root by hypalgesia over the great toe and the dorsum of the foot, perhaps more frequently with sensory diminution over the anterolateral aspect of the calf. Due to dermatome overlap, unusual sensory patterns may occur, diminishing the localizing value of such patterns in protrusions at the fourth lumbar interspace. With few qualifications, involvement of some part of the lateral three toes and the lateral aspect of the foot suggests a disc protrusion at the fifth lumbar interspace, involving the first sacral nerve. A high proportion of such cases will show further a rostral extension of the zone of hypalgesia over the lateral aspect of the calf and thigh, spreading posteriorly over the buttocks to the mid-line of the lumbosacral spine.

B. PRELIMINARY APPRAISAL OF ARMY RESULTS *

Between the early part of 1942 and September 1, 1945, 2,858 cases of rupture of the intervertebral disc were treated by operation in the Neurosurgical Centers of the Zone of the Interior. They comprised approximately 10 per cent. of the total operative load of 29,833 neurosurgical lesions treated during the same period. The final end-result study of this, as well as of other neurosurgical injuries of military import, will be a function of the Veterans Administration or will be conducted under the auspices of the *National Research Council*. The present appraisal, conducted during the war years, was designed solely to evaluate the ability of the soldier to remain on a duty status after operation. The statistics under discussion in this article were secured by The Surgeon General's Office. They demonstrate the size of the problem during the year 1943 and the status of patients so treated as of about August 1, 1944 (Table II) and as of February 1945 (Table III).

There were 2,415 cases diagnosed as herniated nucleus pulposus, representing one out of every 2,000 enlisted men. In addition, officers accounted for about 11 per cent. of all admissions for herniated nucleus pulposus, an admission rate slightly higher than that for enlisted personnel. A 20 per cent. sampling of the cases gave the following results:

Of the 483 cases of enlisted personnel in the sample, 166 were still in Service on August 1, 1944, and 317 had been discharged, a discharge percentage of 66.

Among 328 patients not operated upon, seventy-two were still in Service; the discharge percentage was 78. Of the 126 patients operated upon, eighty-seven were still in Service; the discharge percentage was only 31, which compared favorably with current civilian statistics.

Among fifty-nine officers in the sample, fifty remained in Service; the discharge percentage was only 15. Of thirty-two officers in the sample who had been operated upon, all returned to duty. These figures correlate closely with statistics secured at the Walter Reed General Hospital, which showed a

* Data presented in this discussion were derived from the Surgical Consultants Division, Office of The Surgeon General, Washington, D. C.

mentous irritation, resulting in local backache and the radiation of deep pain to the extremities. It is in cases of this category that disappointments occur after operative intervention, and additional measures are necessary to protect the injured and painful ligamentous structures.

3. In the third group, the symptoms of backache may be mild or lacking, and radiation of pain to the extremity is not extensive. On the other hand, the signs of nerve compression are outstanding. There is muscle weakness with atrophy, definite and unequivocal loss of sensation over the appropriate dermatome, and reflex changes. Relatively few cases of herniated intervertebral discs fall into this category, but many of the spinal-cord tumors do. The authors feel that in those cases the major lesion is one of nerve compression, and local ligamentous irritation is minimum or lacking. Consequently, removal of the pressure agent and decompression of the nerve are followed by almost complete and dramatic recovery, to the gratification of the patient and surgeon alike, if intervention is sufficiently prompt.

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TIBIOTARSAL ARTHRODESIS AFTER ASTRAGALECTOMY

A Report of Eight Cases

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INTRODUCTION

Tibiotarsal fusion has been designed to correct certain structural deformities and to overcome functional disorders which sometimes develop in feet after astragalectomies. The objectives are accomplished by remodeling and fusing the joint space between the tibia and the calcaneus, and by fusing the navicular to the tibia and the cuboid to the calcaneus. It is a revisionary measure, and is used only after astragalectomy has failed.

The first astragalectomy was performed by Fabrig[1], in 1608, for a severe compound dislocation. He found, to his astonishment, that his patient made a good recovery and was able to walk without support. The full possibilities of this important observation remained hidden, however, for nearly three centuries, until Whitman re-introduced the procedure and demonstrated its practical application in the treatment of crippled children. The operation was a major contribution, and soon had a great surge of popularity. It was used by many surgeons, possibly for many different disorders of the foot; and consequently, as might be expected, some of these operations failed. Snedecor, recently reporting on reconstruction of the foot and ankle following war injuries, cited three cases in which astragalectomy had been performed. In one of these cases the result was fair and in one it was reasonably good; in the third case, Snedecor frankly stated that an eventual tibiocalcaneal arthrodesis would probably be necessary.

The incidence of astragalectomy failures is apparently not great; but, if the operation fails, the concomitant deformity and disability are often of such magnitude as to require revision. In this revisionary capacity, tibiotarsal arthrodesis has found its important role; and the operation is, at this moment, a useful and necessary surgical measure.

DISABILITY

The purpose of this paper is not to discuss the principles governing the choice of astragalectomy, nor to attempt an analysis of the reasons for its failure. This has been admirably done by Thompson in a critical re-examination of 100 old astragalectomies and a review of the records of more than 2000 cases. The failures are characterized by pronounced deformity, pain, or instability; one or all of these may be present.

Deformity: Every case of extirpation of the talus presents a characteristic appearance. There is moderate unsightliness of the ankle and some shortening of the foot and leg, due to loss of the bone. Dorsiflexion is limited, or even absent, because of tibiotarsal block or fibrous ankylosis. In the astragalectomy failures, more or less severe deformity is the rule. Equinus is generally present, and is due to severe plantar flexion of the fore part of the foot. Often there is also a marked position of talipes calcaneus (Figs. 1-A and 3-A). The longitudinal arch is elevated and the metatarsal heads are more closely approximated to the heel. The tarsal portion of the foot has been moved dorsally. The plantar fascia is usually contracted, and it appears that the intrinsic flexors have pulled the calcaneus forward and tilted it upward. In some cases there is inversion and twisting of the fore part of the foot; while in others eversion is present, with outward turning of the foot and depressing of the longitudinal arch. Muscle imbalance, in the presence of the stress and strain of weight-bearing on a shortened and already weakened limb, is thought to be the cause of these deformities.

left untreated for a considerable time, the strength never returns. We have a number of these patients who have had foot-drop for six months or a year; they do not recover as well as one would hope, and some of them never recover.

At the present time our criteria for fusion or non-fusion in these cases are indefinite. I believe that we should consider (1) whether or not the patient must do heavy lifting, (2) the presence of abnormal mobility, (3) the presence of a structurally weak lumbar spine, (4) the predominance of back symptoms. As a matter of fact, I am guided to a considerable extent by the desires of the orthopaedic consultants.

In this way, we are running two parallel series of cases, one with fusion and one without fusion. A comparison of these two series should be of real value.

Considering the amount of fusion purely from the point of view of the neurological surgeon, I should feel that, if the fourth disc were ruptured, I would like to have the fourth and fifth lumbar vertebrae and the first sacral segment fused. If the disc is higher up, I do not know. Personally, I do not think I would want my back fused any higher than the fourth or fifth lumbar vertebra. I would rather take a chance than to have fusion done at the third, second, or first lumbar vertebra. I think that what Dr. Love has said is true. Myelography must be considered important, not so much for the diagnosis of ruptured intervertebral disc, but to give us a clue as to whether we are dealing with a fourth disc, a fifth disc, or possibly a third disc, or with multiple lesions. We do not find many multiple lesions at the Massachusetts General Hospital.

With regard to conservative treatment, each individual case must be taken on its own merits. A patient who has fairly bad sciatica and is in danger of becoming a morphine addict should be treated conservatively for a much shorter time than the patient who has remissions. Dr. Van Gorder will remember a patient whom he and I operated upon primarily because he had trouble in his back every time he went grouse shooting. This case was one of the dismal failures. The man was relieved of his sciatic pain, but he had terrific pain in his back. He was relieved by a spine fusion.

I think that the operative treatment of ruptured intervertebral disc has come to stay. I believe that the combined operation of fusion and removal of the fractured portion is something which probably is coming, although of that I am not sure.

Dr. Theodore A. Willis, Cleveland, Ohio: Vertebral anomalies that affect the stability of the lower part of the back predispose the individual to strains and sprains of the muscles and ligaments, thereby giving rise to backache with muscle spasm and restriction of motion. Pain arising from continued or repeated mechanical irritation of a part may be referred to the areas of distribution of any branch of the neuron which supplies the affected part.

In a review of roentgenograms of 1,500 individuals with and without backache and sciatic pain, presented to this Association in 1940, it was noted that vertebral anomalies were not much more prevalent in those individuals complaining of backache than in those who had had roentgenograms for other purposes. In my own experience, patients with even extreme degrees of spondylolisthesis, although they experience backache with exertion, are not prone to complain of sciatic pain.

For these reasons I have been much interested in the late Dr. Dandy's discussions of low-back pain and sciatic pain, and of the treatment of spondylolisthesis, published in the *Journal of the American Medical Association* in 1944 and 1945.

In the earlier paper, Dr. Dandy discussed twenty cases of defective intervertebral disc, not associated with sciatic pain. Sixteen of these cases showed multiple discs, 78 per cent. of which were of the hidden type. Dr. Dandy stated that the weakness of the spine which gives origin to defective discs is the shift in direction of the planes of the lateral articular processes; and he ascribed to the increased mobility of these joints the real source of symptoms, attributing the initial pain to movement of the loose lateral facets, the disc being secondarily affected.

In his discussion of the treatment of spondylolisthesis in 1945, Dr. Dandy expressed the belief that the vertebral displacement of spondylolisthesis is usually responsible for only part of the symptoms present, or at times for none at all. He stated that, in most instances, not the spondylolisthesis or even the disc at its site caused the pain, but rather another disc or discs. Cure of the symptoms, he said, usually depends more on the removal of the other discs than of the one at the site of the defect. This opinion was based on the findings at operation in twenty cases of spondylolisthesis, in eighteen of which there were multiple discs.

Orthopaedic surgeons have been convinced for many years that anomalous and asymmetrical articular processes of the lower lumbar and lumbosacral vertebrae affect the mechanical stability of the spinal column and give rise to clinical symptoms. Dr. Dandy ascribed the real source of these symptoms to the increased mobility of these anomalous joints, but went further by claiming that the loose joints cause disc defects. He insisted that not only the disc at the site of the lesion, but particularly the adjacent discs, must be removed to relieve the symptoms; and that removal of the discs is all that is needed to accomplish this result. He referred to spondylolisthesis as "but an incident in the field of ruptured disks", and as causing fewer symptoms than the contiguous discs. He stated that "the reason for the development of spondylolisthesis is precisely the same as for defective disks, i.e., the outward

on August 7, 1941, at the age of thirteen, for purposes of stabilization and correction of the deformity (Fig. 2-B). Three years after revision, the foot was still solid in a position of 100 degrees and the patient had no pain. Slight varus and slight adduction of the fore part of the foot were present.

CASE 4. L. G., a white female, born February 7, 1931, had *poliomyelitis at the age of* seven months, which left her with severe residual paralysis of both lower extremities. A right astragalectomy was performed at the age of nine years. She returned four years later, with equinus of the fore part of the foot of 125 degrees. Tibiotarsal arthrodesis was carried out on August 27, 1943, for correction of equinus deformity. The patient was last examined on December 7, 1944, at which time the foot was at 115 degrees, stable, and painless.

CASE 5. J. B., a white male, born October 27, 1931, had poliomyelitis at the age of two years Astragalectomy was done on the right foot at the age of five. At eleven years the foot was in equinus of 150 degrees. Tibiotarsal fusion was performed on August 12, 1943, six years after astragalectomy. At last examination, three years after surgical revision, the right foot was in a position of 90 degrees, and was stable and painless.

CASE 6. C. N., a boy, born January 3, 1928, had poliomyelitis at the age of three years with permanent involvement of both lower extremities. Right astragalectomy was done at seven years of age,

FIG. 1-A

Case 2, V. W. Roentgenogram of right foot at the age of fifteen years,—several years after astragalectomy.

FIG. 1-B

Shows same foot after tibiotarsal fusion.

TABLE I

Incidence and Localizing Value of Sensory Loss in 100 Proved Cases of Disc Protrusion

Interspace	No Sensory Loss	Sensory Loss Without Localizing Value	Sensory Loss With Localizing Value
Third lumbar	1	2	0
Fourth lumbar	19	10	19
Fifth lumbar	20	6	23
Totals	40	18	42

ability in the extent of the sensory patterns, when they do appear, is suggestive evidence that the degree of root compression is the limiting factor in the appearance or non-appearance of sensory changes, a fact that cannot be fully evaluated by gross inspection of the protruding disc fragment at operation.

The distribution of the sensory dermatomes in man has been studied by Déjerine, Head, Foerster, and recently by Keegan (Figs. 1, 2, and 3). They have been described following differential root section, stimulation of divided posterior roots, chemical irritation of cord segments, after the appearance of herpes zoster, after trauma, and after operative resection of sensory roots, involved in neoplastic growth or compressed by a disc fragment. The method used by Foerster of isolation of a single root by rhizotomy of the adjacent caudal and rostral roots, following the experimental work in monkeys reported by Sherrington, has demonstrated, in all probability, the most accurate picture of the lumbosacral dermatomes pertinent to disc surgery.

Two points in Foerster's work are of significant import to neurosurgeons interested in defining the sensory patterns characteristic of disc compression. In the first place, it is apparent that there is considerable overlap in the distal distribution of the sensory dermatomes of the fourth and fifth lumbar roots, innervating the large toe and the dorsomedial aspect of the foot. Clinical experience with disc lesions at the fourth lumbar interspace, involving the fifth lumbar root, has shown, however, that involvement of the great toe, dorsum of the foot, and anterolateral aspect of the calf, either by subjective sensory changes or hypalgesia, is of specific diagnostic aid. Involvement of the anterolateral aspect of the calf was observed more frequently in this particular series than was that of the large toe and dorsum of the foot. There may be considerable variation in the sensory patterns in the calf. Unless the large toe and dorsum of the foot are involved, the sensory patterns observed before operation in disc compressions of the fifth lumbar root at the fourth lumbar interspace are not of specific or of localizing value (Fig. 4).

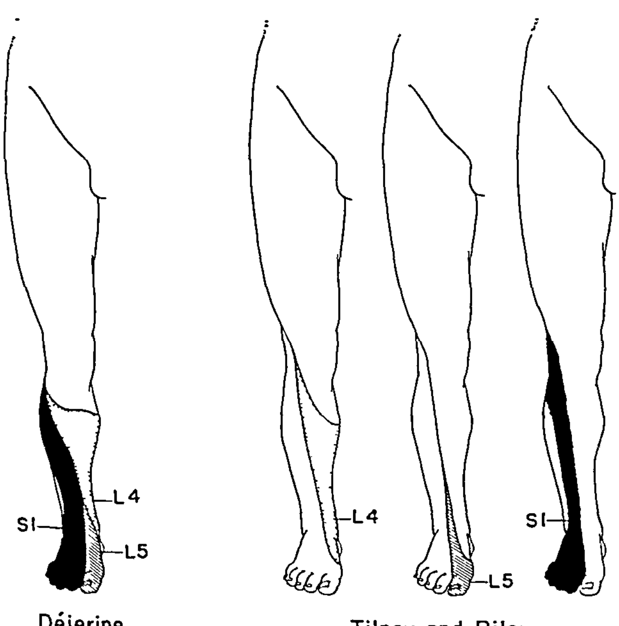

Fig. 1

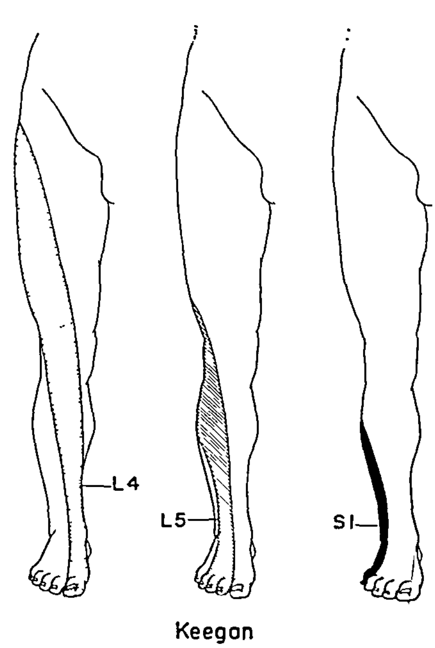

Fig. 2

Fig. 1: Distribution of the sensory dermatomes of the fourth and fifth lumbar and first sacral roots (adapted from Déjerine and Tilney and Riley[2,6]).

Fig. 2: Well-demarcated sensory dermatomes and denial of overlap in Keegan's chart[5]. The rostral extension of the dermatome of the fourth lumbar root illustrates, in part, this phase of his study.

Fig 3-A
Case 7, E K. Roentgenogram of left foot, eighteen years after astragalectomy

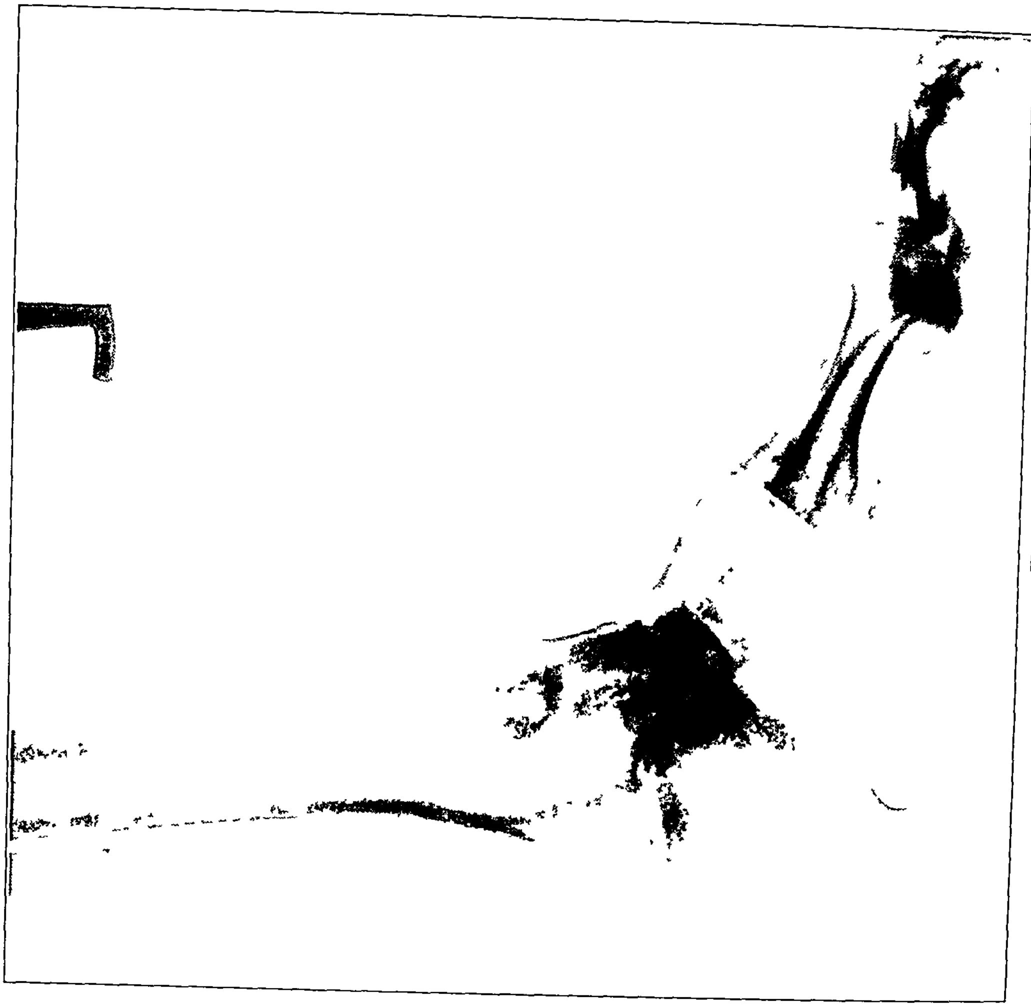

Fig. 3-B
Shows same foot, twelve weeks after tibiotarsal fusion

There is little dispute concerning the distal distribution of the sensory dermatome of the first sacral root. Overlap is minimal and, with compression of this root, alterations of normal sensibility may be expected over some part of the lateral three toes and over the lateral aspect of the foot. When such changes are found in a suspected disc lesion, their localizing value is evident. This statement must be qualified by the fact that, in two instances of herniation at the fourth lumbar interspace, sensory changes characteristic of involvement of the first sacral root were found, suggesting a more medially placed protrusion. In half of the cases in this series showing distal sensory patterns characteristic of involvement of the first sacral root, the sensory loss could be demonstrated rostrally as a narrow or wide band, extending up the posterior and lateral aspects of the leg and thigh, terminating at the mid-line of the lumbosacral spine. In some instances, involvement of the sensory roots of the second and third sacral may have been responsible for this phenomenon, but in a considerable number, the band of hypalgesia lay too far ventrally to fit the customarily accepted dermatomes of the second and third sacral roots (Figs. 5, 6, and 7).

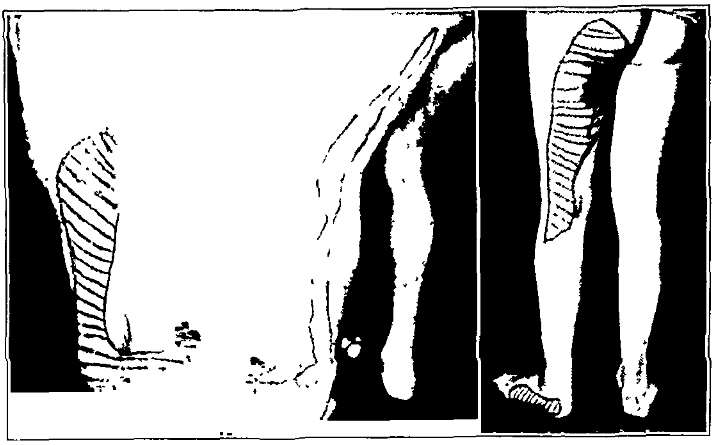

Fig. 5

Sensory patterns with disc protrusion at the fifth or lumbosacral interspace, with compression of the first sacral root. A fairly characteristic pattern, involving lateral toes, lateral aspect of foot, and posterolateral calf, is shown at the left. Second view shows rostral extension of a similar sensory pattern to involve the posterior aspect of the thigh. At the right may be seen splitting of a sensory pattern with possible involvement of the lower sacral roots. The burn occurred in an area of analgesia.

Conclusions

The preoperative sensory patterns seen in instances of classical disc protrusion are dependent upon at least the two factors of varying compression and the well-recognized overlap of sensory dermatomes. They may be influenced further by the location of the disc protrusion in any single interspace and by single or multiple root compression. Such patterns cannot be compared with those obtained by rhizotomy, although in many instances they are quite similar in distribution.

Roughly, half of the patients with indisputable disc protrusions show sensory changes that are of

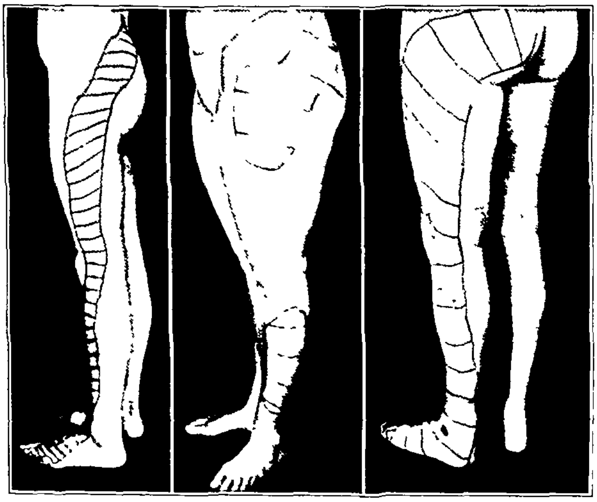

Fig. 6

Fig. 7

Fig. 6: Rostral extension of sensory pattern over buttocks to mid-line of lumbosacral spine may be seen at left. Center view shows evidence of splitting of a sensory pattern, similar to those portrayed in the other two views. At right is seen another instance of a symmetrical rostral extension of a classical first sacral dermatome, placed more ventrally than the customary dermatomes of the second and third sacral roots.

Fig. 7: Classical sensory pattern of almost complete transverse protrusion at the lumbosacral interspace, involving the first sacral roots and distal sacral segments.

ANALYSIS OF CASES

All of the eight patients were paralytics, who had had poliomyelitis at an early age with permanent disability of the lower extremities. Five were males and three were females. Seven of the eight revisions were on the right side, although two of the patients had had bilateral astragalectomies. The onset of the poliomyelitis had been between seven months and seven years of age. The astragalectomies had been done between the ages of five and fifteen years. The revisions had been performed between the ages of eleven and thirty-three years, and averaged a little over seven years after astragalectomy. Before revision, two patients had pain on weight-bearing, two presented calcaneus, and four equinus,—which was severe in two. Four had cavus deformities, two of which were severe. Four feet showed varus and one valgus. After revision by tibiotarsal fusion, none of the feet were painful and all were stable. Satisfactory correction of deformity was obtained in every instance; the average position of the foot for females was 102 degrees; for males, it was 98 degrees. One patient was enabled to discard a brace after the operation, and all patients were definitely improved. In this series, arthrodesis occurred in each case without delay. In one patient, calcaneotibial arthrodesis had previously been attempted for purposes of revision, but had failed.

SUMMARY

In extirpation of the talus, in addition to the noticeable disfigurement of the ankle, some shortening of the extremity occurs with limitation of dorsiflexion. Disabling deformity occurs in some cases. Some ankles are definitely not stable, and consequently are painful. Deformities, especially if severe, demand operative correction, if all the criteria of a good foot and ankle are to be satisfied. This can be accomplished by tibiotarsal fusion.

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TABLE III
HERNIATED NUCLEUS PULPOSUS
(Status as of February 1945 of Patients Admitted During 1943)

	All Cases			Method of Treatment					
				Excision or Laminectomy			No Operation		
	No.	Per Cent.	Total	No.	Per Cent.	Total	No.	Per Cent.	Total
Enlisted men									
In Service	90			50			40		
Separated	360	80	450	83	62	113	277	87	317
Officers, male									
In Service	44			28			16		
Separated	18	29	62	11	28	39	7	30	23
Females									
In Service	5			3			2		
Separated	3	38	8	1	25	4	2	50	4
Total									
In Service	139			81			58		
Separated	381	73	520	95	54	176	286	83	344

discharge percentage of less than 10 among officers. These statistics suggested that Army neurosurgeons were doing a fairly good job during 1943 in the rehabilitation of patients with disc injuries. There were two extraneous factors favorable to these results, above and beyond the professional problem. In the first place, the Army needed restricted-duty personnel, and for this reason there was considerable pressure upon surgeons to return the men to duty. In the second place, officers, with their obviously greater reward for return to duty, ranked as an easier group for rehabilitation.

The picture changed considerably during the latter half of 1944 and the early part of 1945. Directives were issued, stating in effect that all patients operated upon for herniated nucleus pulposus should be returned to permanent restricted duty, under the profile supplement of Mobilization Regulations 1–9, issued May 22, 1944. Furthermore, under War Department Circular No. 212, dated May 29, 1944, the return to duty of a patient without special qualifications, who could not do a full day's work, was prohibited. This change in the manpower requirements of the Army was quickly recognized by patients, and increasing difficulty was experienced in securing alleviation of symptoms. In the second place, these patients did not respond well to the reconditioning program, which did not appear well adapted for the care of low-back injuries. (This phenomenon was also noted in England.) In many instances, the symptoms recurred, and many men were readmitted to the hospital.

A re-evaluation of the cases of herniated nucleus pulposus treated in 1943 (Table II), again by the method of a 20 per cent. sampling of the entire group, was carried out by the Medical Statistics Division of The Surgeon General's Office on March 24, 1945. The percentage of patients discharged after operation had by then risen from 31 to 54, and the total percentage of the patients who were discharged, both operative and non-operative cases, had risen from 66 to 73 (Table III). This reflected, in all probability, the influence of personnel requirements upon a neurosurgical problem, as well as the inability of patients with this syndrome to withstand the various difficulties of Army life.

NOTE: The speaker is indebted to Guy Odom, M.D., for several of the clinical photographs of preoperative sensory patterns.

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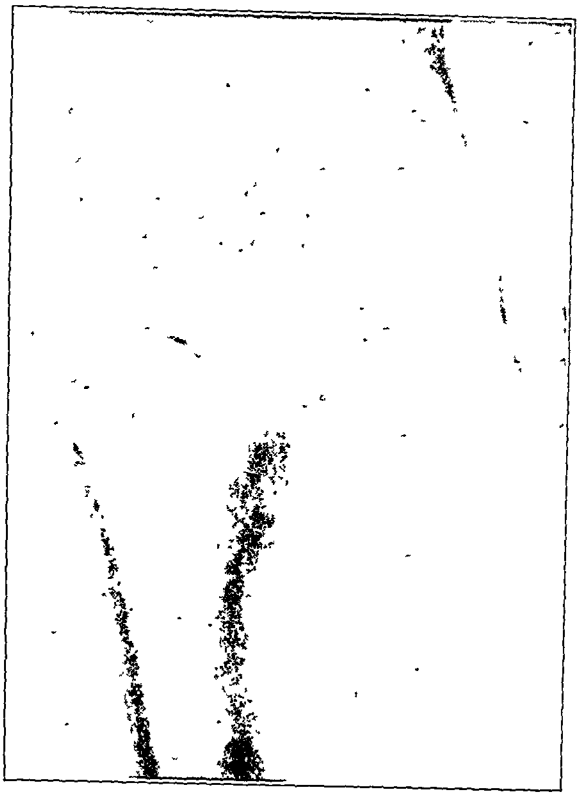

FIG 1-A

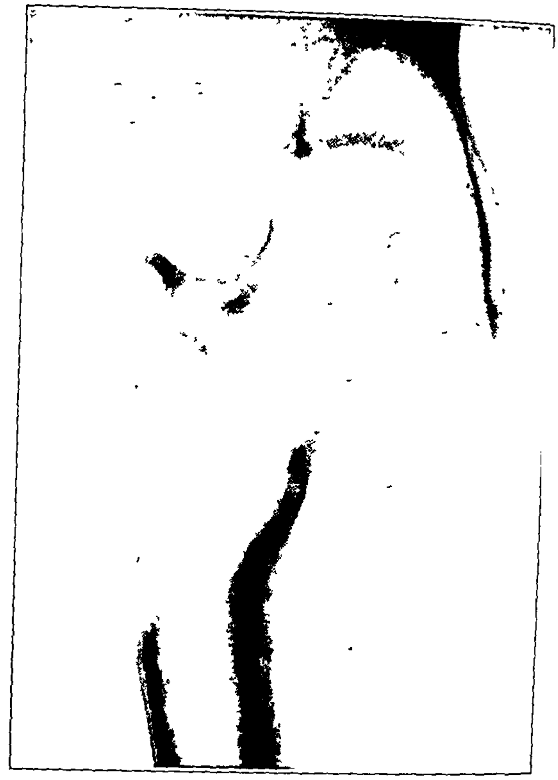

FIG. 1-B

Fig. 1-A: Case 1. There are two oval areas of decreased density at the inferior border of the subcapital region of the femoral neck. There is marked sclerosis of the medial surface of the neck and shaft below these areas. Note that the articular cartilage space is slightly narrowed and that there is lipping at the margins of the femoral head.

Fig. 1-B: Postoperative roentgenogram.

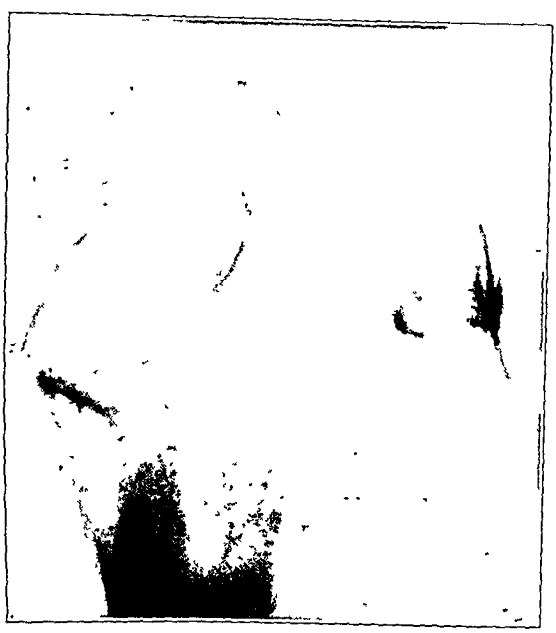

FIG. 1-C

Fourteen months after operation. The operative defect is partially filled in. The previously noted hypertrophic changes in the joint are more marked.

the lower border of the glutaeus maximus. Reflexes and sensation were unaltered. The knee joint and the ankle joint appeared normal. Routine laboratory examination revealed a moderate hypochromic anaemia and a positive tuberculin reaction. Chest roentgenograms were normal, and there was no fever. Roentgenograms of the pelvis revealed two oval areas of decreased density on the medial aspect of the neck of the right femur. Around and below these areas there was sclerosis of the regional bone. There were mild degenerative changes in the hip joint, as evidenced by a slight narrowing of the cartilage space and lipping at the margins of the femoral head (Fig. 1-A).

At operation a few days later, the joint was first entered anteriorly. The synovial membrane showed marked villous proliferation, and the joint space contained about 100 cubic centimeters of clear xanthochromic fluid. There was marginal osteophyte formation about the head of the femur, but the articular cartilage appeared to be normal. Specimens of the synovial membrane and of the cartilage were removed for biopsy, fluid was taken for examination, and the wound was closed. Because of the possibility that the bone lesion was infectious, the trochanteric region of the femur was then exposed through a separate incision, and the lower portions of the interior of the femoral neck were explored. All the bone that had shown changes by roentgenogram was removed, but no definite lesion could be identified grossly (Fig. 1-B). The wound was closed routinely.

The patient was immediately relieved of her pain, and she commented upon this as soon as she awakened from the anaesthetic. Healing was uneventful. Culture and guinea-pig tests of the material removed from both operative sites were negative. The bone defect filled in slowly without return of

Pain: Although pain is not a constant finding, it sometimes occurs after astragalectomy, and, when present, is explained upon the basis of excessive strain, synovitis, traumatic arthritis, or instability of the tibiotarsal joint. It may be quite disabling.

Instability: Loss of stability results from muscle imbalance, deformity, or both. When this condition exists, stabilization is indicated, even though excessive deformity may not be present.

All these obnoxious factors may cause impairment of gait, decrease in function, and loss of endurance. Tibiotarsal arthrodesis rectifies these factors by correcting the deformity and stabilizing weak and painful joints.

OPERATIVE PROCEDURES

Surgical approach is made through an anterior longitudinal incision over the tibiocalcaneal joint. Sufficient exposure is needed to view well the anterior borders of both malleoli, as well as the articular surfaces of the tibia, the calcaneus, the navicular, and the calcaneocuboid joint. As the calcaneocuboid joint may be laterally placed, it is sometimes advisable to expose this joint through a separate incision over it. All cartilage, and the fibrous and fibrocartilaginous tissue are completely removed from the articular spaces. Correction of deformity is obtained by removing bone substance in sufficient amounts to allow restoration of good weight-bearing alignment of the foot with the leg, and to correct any malignment between the fore and rear portions of the foot. Every attempt must be made to adjust the foot as accurately as possible, placing it in exact neutral position or, better, in slight valgus and in proper equinus. When properly fitted, the raw bony surfaces of the joints are approximated; and supplemental bone, in the form of chips, obtained from the anterior surface of the tibia above the joint, is distributed across the lines of arthrodesis to facilitate prompt union.

The degree of equinus is of major importance. In most instances a position of 95 degrees (Fig. 4-B) for boys and 100 degrees for girls is the optimum position for a stiff ankle, since at these angles walking is easy and the gait is nearly normal, provided mobility of the anterior tarsal and metatarsal joints is preserved. Fusion at a right angle is not desirable, since it produces an awkward calcaneal gait. Equinus in excess of 10 degrees is undesirable, because of the resultant undue strain on the tarsometatarsal region and because of the difficulty of barefoot walking.

CASE REPORTS

CASE 1. C. S., a white girl, was born on February 3, 1929. She had poliomyelitis at the age of three with resulting severe paralysis of both lower extremities. Several surgical procedures had been necessary, including bilateral astragalectomy at the age of eight years. At the age of twelve, the right foot showed no evidence of muscle power. Mild cavus, moderate varus, and 10 degrees of equinus were present, with pain on weight-bearing because of lateral instability. Since she wore no brace on this side, an operation was advised for increased stabilization. Tibiotarsal fusion was performed at the age of twelve,—four years after astragalectomy. Solid union was obtained; and at the last examination, five years after the surgical revision, the foot was in a position of 95 degrees. There was no cavus or pain; and the foot was stable, although still in slight varus.

CASE 2. V. W., a white girl, was born June 18, 1924. She had an attack of poliomyelitis at the age of three years, with marked residual paralysis of both lower extremities. At the age of fifteen years, having previously had an astragalectomy on the right, her foot was in moderate valgus and severe cavus (Fig. 1-A). Revision was necessary for correction of the deformity; and a tibiotarsal arthrodesis was attempted, but fusion failed. Two years later the foot was in equinus, marked calcaneus, and varus. A second revision was done on September 4, 1941. Good correction was obtained and prompt fusion resulted. When last examined, eight months after the last revision, the foot was at 98 degrees; [illegible] stable, free from pain, and in very slight valgus (Fig. 1-B).

CASE 3. R. W., a white male, was born October 14, 1928. He suffered poliomyelitis at seven years, with severe residual involvement of both lower extremities. Astragalectomy on the right foot at the age of nine years. Four years afterward there was marked ca[illegible] the fore part of the foot, and varus of the heel (Fig. 2-A). Tibiotarsal fusion of the [illegible]

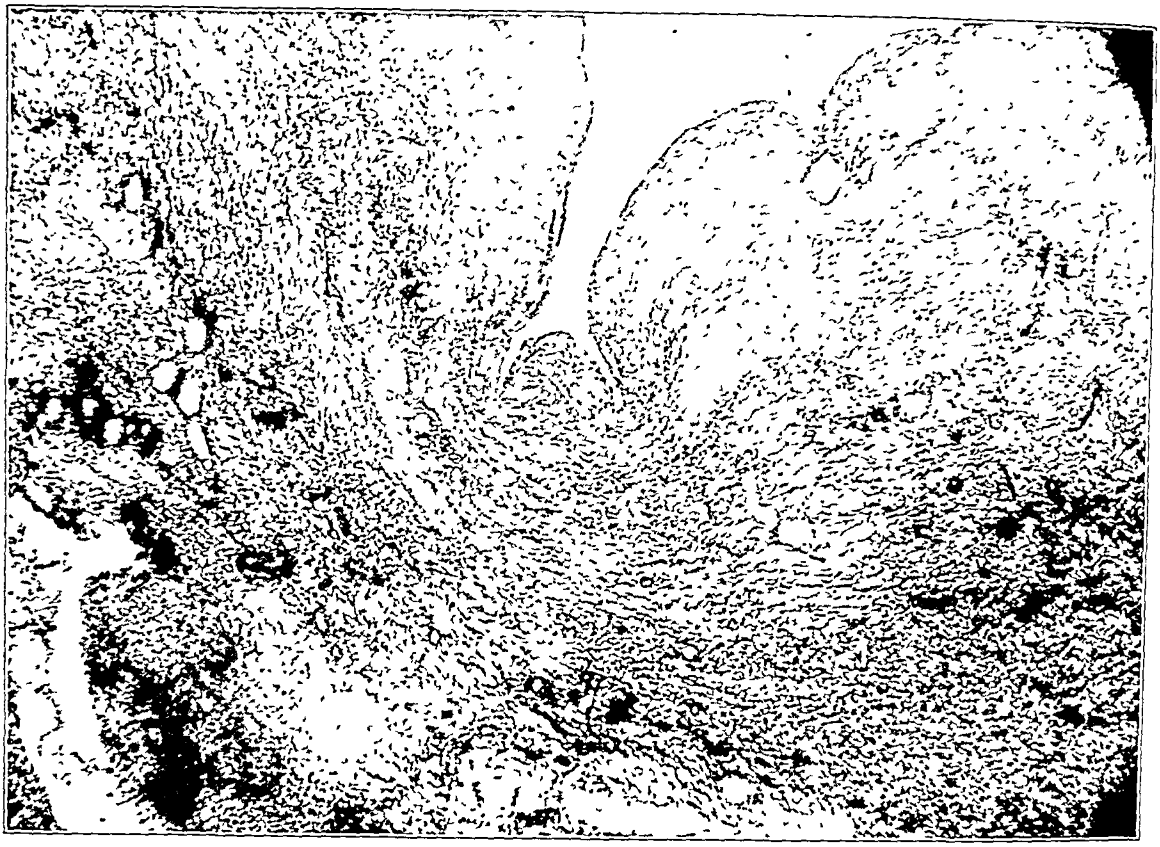

FIG. 1-F

Photomicrograph (× 58) of synovial membrane of the hip joint, showing thickening and proliferation, engorged blood vessels, heavy infiltration with chronic inflammatory cells, and fibrin deposits.

pain, but the limitation of motion, which was due to the hypertrophic changes in the joint, is still present (Fig. 1-C).

Sections of the bone chips removed from the femoral neck showed, in addition to the regional sclerosis, a small central lesion which contained, in a background of vascular fibrous tissue, masses of relatively acellular pink-staining material which had the appearance of osteoid tissue. This tissue was irregularly calcified both at the center and also at the periphery of the lesion. Giant cells were present, but were not numerous (Fig. 1-D). Section of the articular cartilage from the lower margin of the head showed the extent of the degenerative changes (Fig. 1-E), while Figure 1-F showed the proliferation and intense chronic inflammation of the synovial membrane.

CASE 2. E. G. This boy of thirteen years was first seen in August 1945, complaining of pain in his left elbow, which had begun three months before. This pain was intermittent and lasted only a few seconds. It was aggravated by activity and relieved by heat. Swelling, which had been present since the onset, increased and motion gradually became restricted. There was no history of trauma, but the patient had recently recovered from a prolonged illness with scarlet fever.

Physical examination revealed moderate swelling of the left elbow joint, which was distended with fluid. The joint was not hot, nor was there specific tenderness. Flexion and extension were both limited by about 20 degrees and any attempt to increase this range caused generalized pain. There was no atrophy, and the neurological examination was normal. Laboratory examinations were normal except for a persistently elevated sedimentation rate (25–38 millimeters per hour). Chest roentgenograms revealed no abnormalities, and there was no fever. The skin tuberculin test was twice negative. Fluid, aspirated from the joint on several different occasions, contained no organisms; there was no growth on culture, and tuberculosis was not produced in a guinea pig.

Roentgenograms of the elbow revealed a slight thickening of the lower end of the humerus and an irregularity of the ossification center of the trochlea (Fig. 2-A). The arm was immobilized in a plaster dressing, and the child was followed in the Out-Patient Department.

For the next five months the patient was without any appreciable change in symptoms, findings, or roentgenographic appearance. However, in February 1946, nine months after the first symptoms, the roentgenogram showed a distinct lesion in the olecranon fossa (Fig. 2-B). This round lesion occupied the entire fossa and had a center of mottled, increased density. The lower end of the humerus was markedly thickened by reactive bone formation and had lost its usual contour.

Laboratory studies and examination of the joint fluid were unchanged except that the sedimentation

followed by left astragalectomy four months later. At the age of fourteen he returned with the right foot in varus, adduction of the fore part of the foot, calcaneus, and cavus. The ankle was unstable; he wore a brace on the right and used crutches. Tibiotarsal arthrodesis was done on the right on June 18, 1942. Good correction was accomplished, and prompt union followed. The patient was able to discard the brace, although he continued to use crutches. At last examination, three years after the revision, the right foot was neutral laterally, in a position of 100 degrees, stable and free from pain. Although the muscle power at the right knee was zero, he was able to get along with the help of crutches, but without the use of a brace.

CASE 7. E. K., a white male, was born December 27, 1912. He had poliomyelitis at the age of four years with residual paralysis, confined to the left lower extremity. He wore a brace for support until he had an astragalectomy at the age of fifteen years, after which he was able to discard the brace. Over the passing years, however, the foot gradually assumed a position of deformity and pain developed, espe-

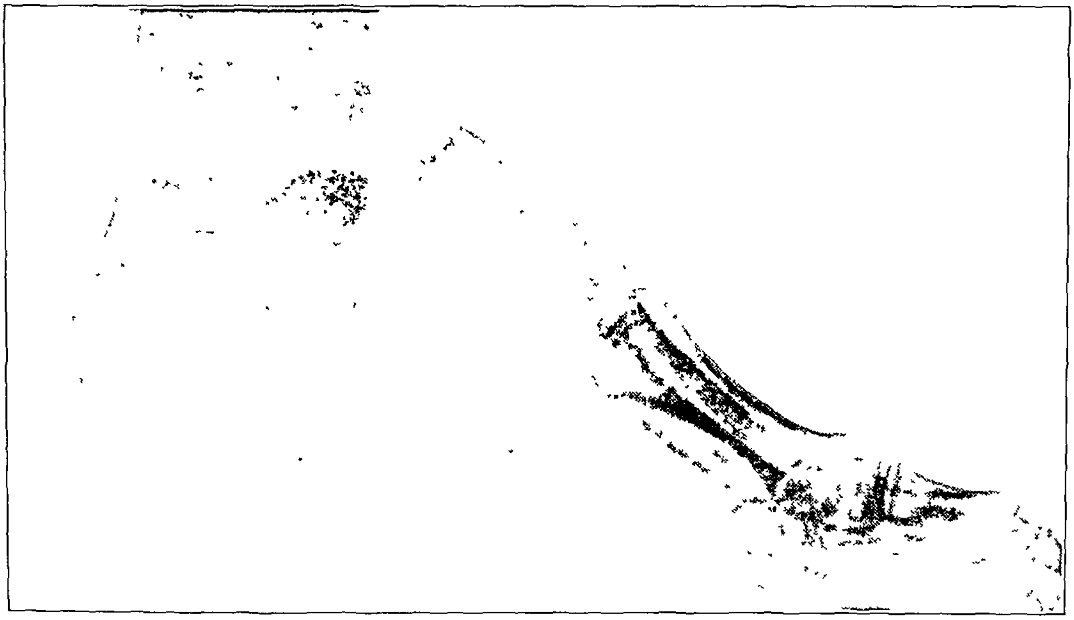

FIG. 2-A
Case 3, R. W. Roentgenogram of right foot, four years after astragalectomy.

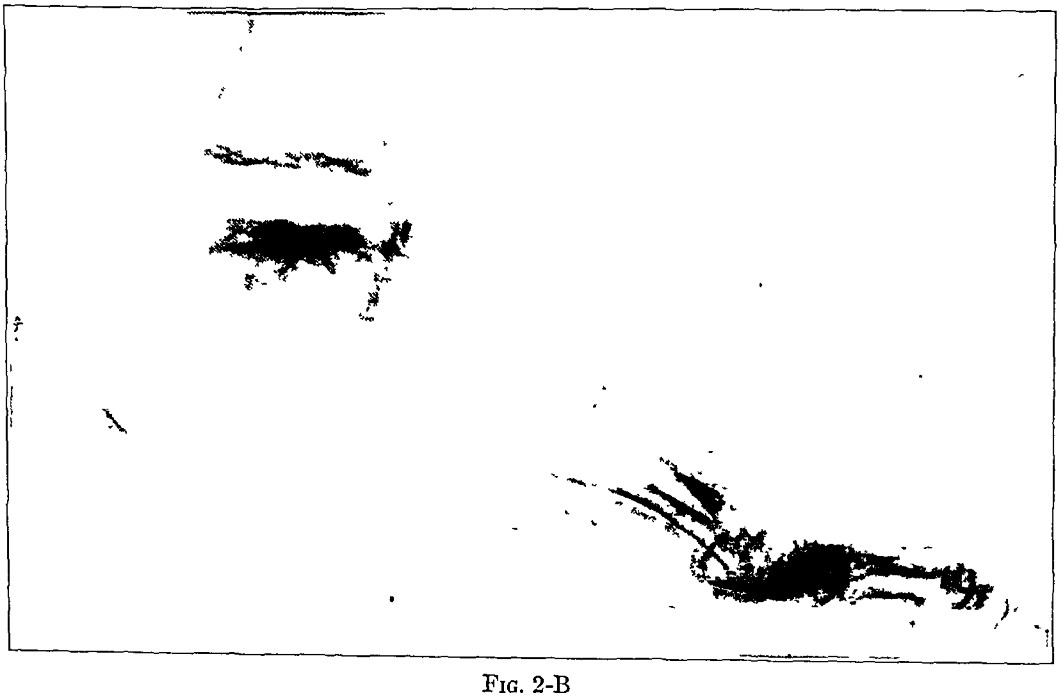

FIG. 2-B
Same foot, twelve weeks after tibiotarsal fusion.

Healing of the wound was prompt, and there was no pain after the first postoperative day. The range of motion increased gradually, and four months after the operation it was complete.

Sections showed a very active lesion. There was a large amount of fibrous tissue in which were found many osteoblasts and osteoclasts and also giant cells of the foreign-body type (Fig. 2-D). In the fibrous tissue there was an irregular pattern of trabeculae which under higher magnification could be seen to be composed largely of osteoid tissue. The degree to which the osteoid tissue was calcified varied greatly from place to place (Fig. 2-E). Section of the synovial membrane showed, as in the previous case,

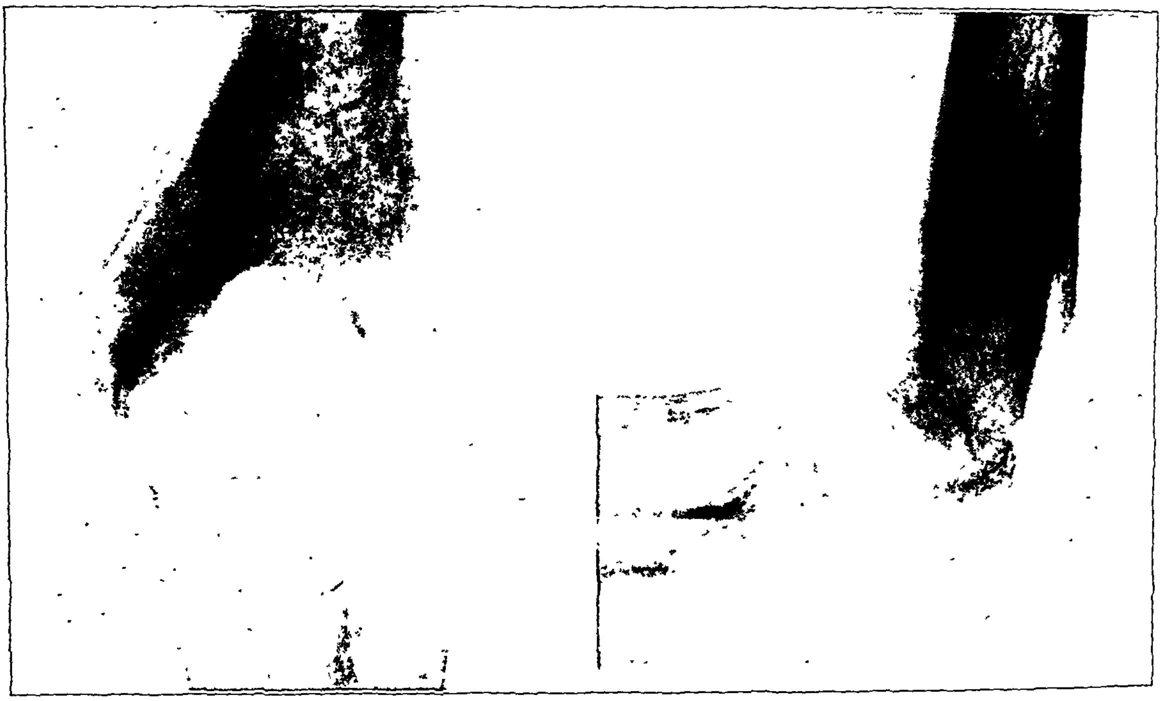

Fig. 2-C

Postoperative roentgenograms.

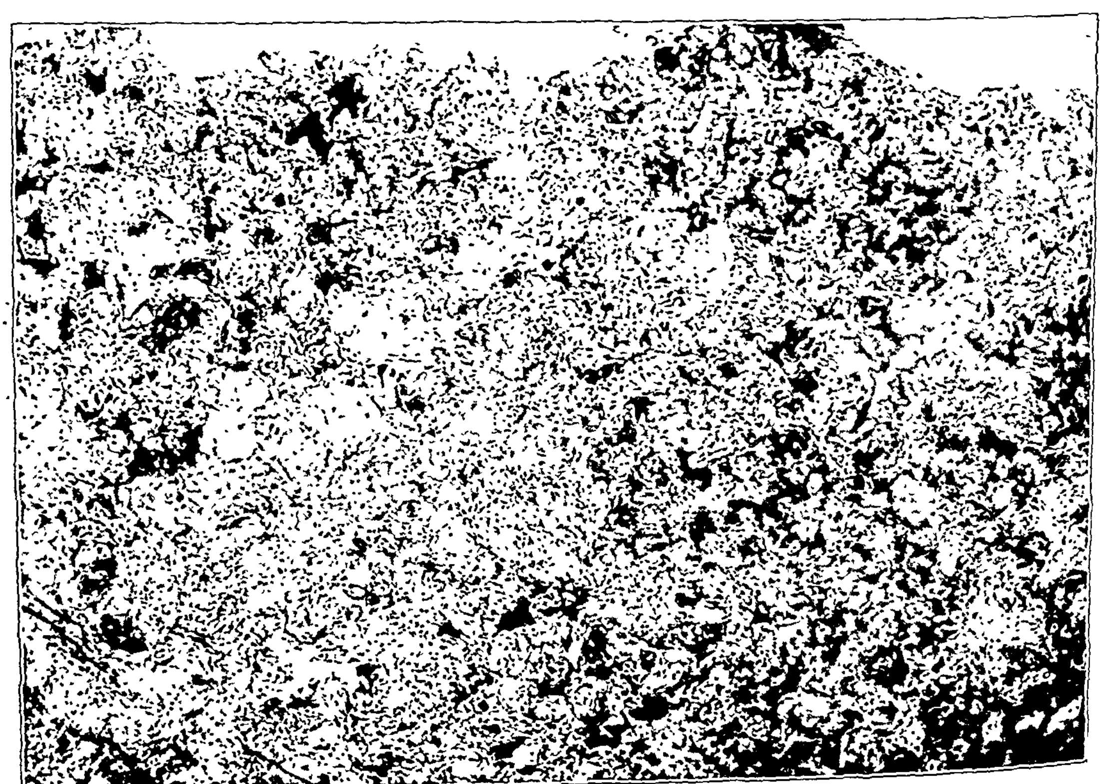

Fig. 2-D

Low-power photomicrograph (× 55) shows the very active vascular fibrous stroma in which are trabeculae of irregularly calcified osteoid tissue.

cially when the patient walked up a hill or climbed stairs. At the age of thirty-three years, eighteen years after astragalectomy, the fore part of the left foot was in severe equinus of nearly 180 degrees (Fig. 3-A). The plantar fascia was tight and contracted; there were cavus and calcaneus. A special shoe had been necessary for years. Tibiotarsal arthrodesis was performed on March 21, 1946. Excellent correction and alignment were obtained and prompt fusion resulted. Twelve weeks after the operation (Fig. 3-B), the patient was supplied with a regular shoe, given a three-fourths-inch lift to the heel, and weight-bearing was permitted. The foot is now well corrected, stable, and free from pain. No special shoe is needed.

CASE 8. J. G., a white male, was born February 27, 1930. He had poliomyelitis at the age of two years with permanent residual involvement of both lower extremities, particularly the right. Astragalectomy was performed on the right at the age of seven years. Further reconstructive surgery was performed later upon the right lower extremity, above the foot. At the age of sixteen years, the foot was stable laterally, but the heel did not touch the floor and the patient walked with drop-foot gait (Fig. 4-A). Tibiotarsal arthrodesis was done on March 21, 1946. Good alignment was obtained, and prompt fusion resulted with the foot at 95 degrees. Twelve weeks after the operation, roentgenograms showed that fusion was present (Fig. 4-B). The patient was therefore supplied with a regular shoe, and weight-bearing was permitted.

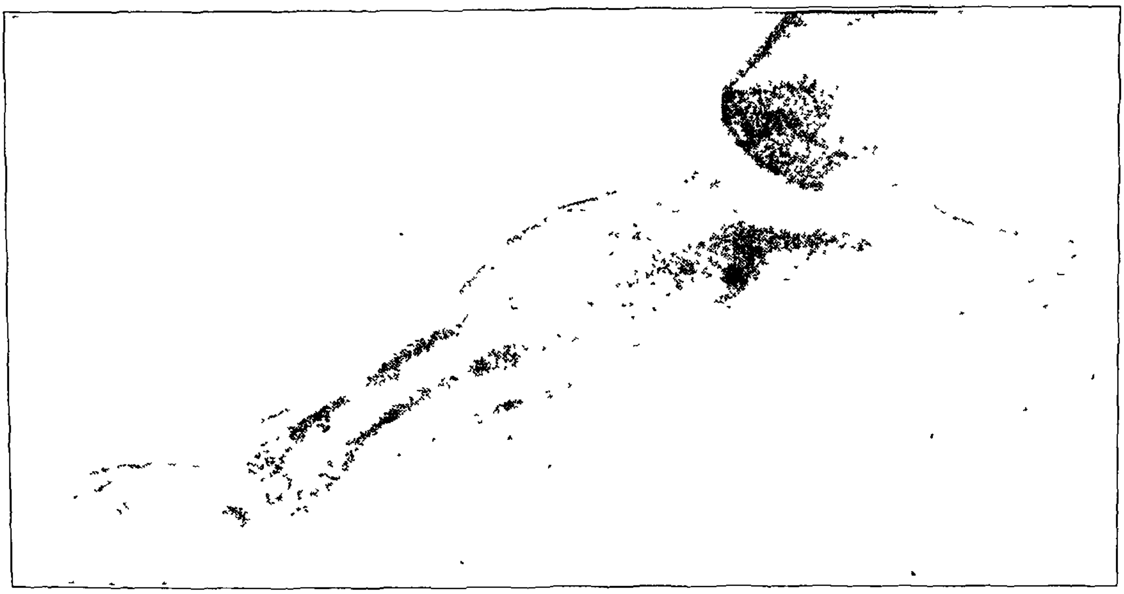

FIG. 4-A
Case 8, J. G. Roentgenogram of right foot, nine years after astragalectomy.

FIG. 4-B
Same foot, twelve weeks after tibiotarsal fusion.

DISCUSSION

Many skeletal lesions produce pain in distant joints which are themselves free of disease. Thus it is common to see a child with hip disease whose chief complaint is pain in the knee. No matter how long the exciting focus exists, and with it the symptom of "referred pain", the knee joint remains normal. Treatment of the disorder in the hip results in disappearance of the pain in the knee, and there are no residual effects in the latter joint.

Joints are also seen which are the site of actual inflammatory changes induced by nearby bone lesions which do not directly involve the joint. Occasionally, a focus of infection in the metaphysis of a long bone will excite a secondary reaction in the adjacent joint, which will become swollen, tender, and filled with fluid. If the joint is inspected, the synovial membrane is seen to be thickened and injected. The joint fluid is increased and may contain fibrin flecks. Though it commonly exhibits more than the usual number of cells, it is sterile. Removal of the bone focus will cause the joint symptoms to subside without specific therapy.

A similar reaction is known to arise in response to non-infectious bone lesions, such as the localized fibrous defects which occur in the metaphysis[3].

Apparently, the joint manifestations of the two cases here reported are of the same nature and represent a secondary reaction to nearby osteoid osteoma. That the inflammatory changes, if they persist long enough, can themselves cause subsequent degeneration of the joint surfaces, is well illustrated by the first case. That these changes subside spontaneously, after removal of the osteoid osteoma, is shown by the second case.

These cases constitute further evidence in support of Jaffe's contention that osteoid osteoma is not an infectious lesion. Although both patients had sufficient joint symptoms and findings to lead to a suspicion of primary arthritis, neither one had any systemic findings compatible with an infectious process, nor did chemotherapy influence the course. In both, the joint fluid and tissue from the bone lesions were sterile on culture and did not produce lesions in the guinea pig. In both, the sections of the synovial membrane showed only non-specific inflammatory changes. Finally, in both patients the acute joint symptoms subsided promptly following excision of the osteoid osteoma and have not returned.

If removal of the bone lesion is delayed, and the inflammation of the joint persists for a long time, permanent damage to the articular structures may supervene.

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OSTEOID OSTEOMA ASSOCIATED WITH CHANGES IN ADJACENT JOINT

Report Of Two Cases*

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In 1935 Jaffe first recognized the clinical and pathological entity which he named osteoid osteoma. Since that time, it has become obvious that the condition is by no means a rarity, and case reports have appeared with increasing frequency[1,2,7].

The general characteristics of this lesion, which several times have been presented in detail, are now well known[4,5,6]. Although it may be seen at any age, it is most common in patients between ten and thirty years old. It has been noted in all parts of the skeleton except the ribs and the skull, but its favorite sites are the long bones of the lower extremity.

The chief clinical complaint is of pain, which at its onset may be fleeting, but which gradually becomes constant and severe. It is usually worse with exercise, is most acute at night, and often prevents sleep or awakens the patient. If the lesion is superficial, there may be moderate swelling, but no signs of inflammation appear. There is acute point tenderness at the exact site of the lesion, and the ability to localize the trouble accurately is characteristic even in very young patients. There are no systemic symptoms or signs, and the appearance of fever or leukocytosis should cast doubt upon the diagnosis. The roentgenograms show distinctive changes when the lesion is fully developed, but it may be normal in the early stages of its evolution. The main portion of the eccentric lesion is radiolucent. The periphery is marked by a ring of dense bone, and the center may also be dense. The regional bone about the osteoid osteoma always becomes hypertrophied. In cancellous bone, the surrounding sclerosis is never so marked as that seen when the lesion is at or near the cortex, where the hypertrophy may be enough to obscure the nidus.

The lesions do not grow appreciably even over a period of years, but they tend to become increasingly painful and disabling. They respond dramatically to surgical removal, and show no tendency to spread or to recur.

The pathological picture is also unmistakable. There is always a background of very vascular fibrous tissue in which giant cells, osteoblasts, and osteoclasts are scattered. In this stroma there arises an irregular Paget-like pattern of trabeculae, which are in large part composed of osteoid tissue. Slowly and irregularly the osteoid tissue calcifies to become bone which is mixed with the osteoid tissue.

Occasionally, a lesion which is situated near a joint will produce changes in that joint which may be severe enough to result in hypertrophic arthritis. In osteoid osteoma of the spine, these changes nearly always appear in the small joints, and several such cases are being reported elsewhere. Among the thirty-three cases diagnosed at the University of Chicago clinics are two in which marked changes occurred in major joints. These two cases form the basis of this report.

CASE 1. J. M., a sixteen-year-old girl, was first seen in December 1944, because of pain in the right hip, which had begun two years before. At first the pain was intermittent and was noted when she arose after sitting for long periods. Six months later, she began to limp, and the pain gradually became more severe. For a year before her admission, there was an almost continuous dull ache about the hip which radiated to the lower part of the back on the right side and also, occasionally, down the inner aspect of the right thigh. The patient was frequently awakened at night by pain. There was no history of systemic disease or of trauma. A loss of twenty-five pounds during the preceding year was ascribed to her difficult domestic arrangements, which had led to actual malnutrition.

The physical examination disclosed no abnormalities except of the right lower extremity. There was no atrophy, but the patient walked with a limp. All movements of the right hip were limited, and any attempt to produce a full range of motion caused pain. There was tenderness to deep palpation at

*This work was supported by the Douglas Smith Foundation.

56 millimeters. The pulse rate was 96 per minute, with occasional premature systoles. The heart was not appreciably enlarged, the apex beat being palpable nine centimeters to the left of the sternum in the fifth interspace. A non-transmitted systolic murmur was noted in the aortic and mitral areas. The genitalia showed senile changes. There was an ecchymotic area over the right supra-orbital ridge,—a result of the fall. A marked kyphosis of the upper thoracic spine was noted, which had not been present six years previously. Tenderness was elicited on pressure over the ischial spines and tuberosities, and also over the superior ramus of the right pubis. Active flexion of the right hip was absent, due to pain; and passive motion caused the patient to complain of pain.

Roentgenographic Findings

A roentgenogram of the pelvis showed no fracture, but disclosed the marked osteoporosis for the first time and led to examination of the other bones. Great rarefaction of both tibiae and humeri was present, with numerous pseudocystic areas, together with thinning of the cortex and lacunae-like erosion of the endosteal surface of the cortex (Figs. 1-A,

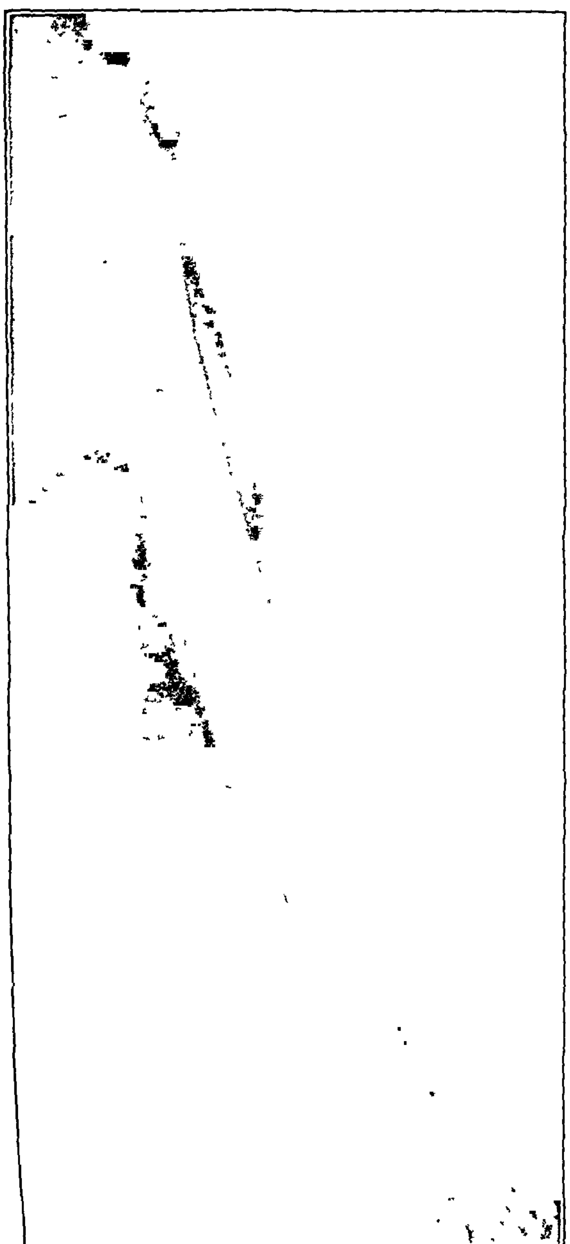

FIG. 1-A

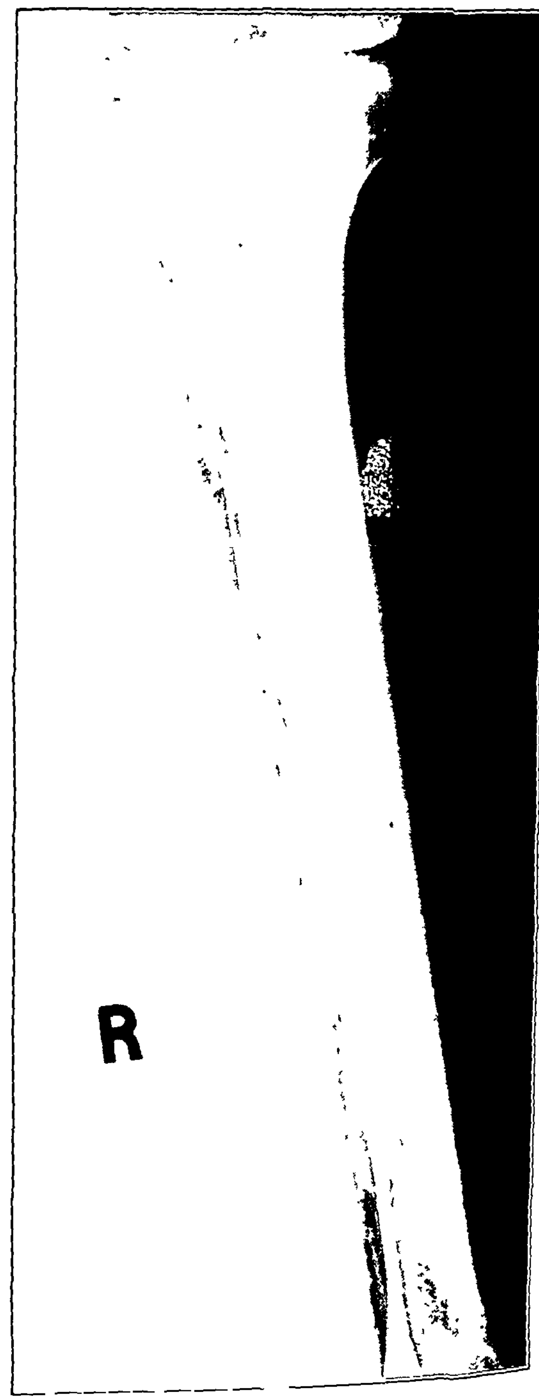

FIG. 1-B

Roentgenograms taken one month before patient's death, showing the extreme osteoporosis of all the bones, with cystlike areas of rarefaction throughout. Note the lacunae-like erosions of the endosteal surface of the cortices of the femoral shafts (Fig. 1-C). All bones were similarly affected, there being no normal-appearing bone between any of the cystic areas. The roentgenographic changes simulate those of hyperparathyroidism.

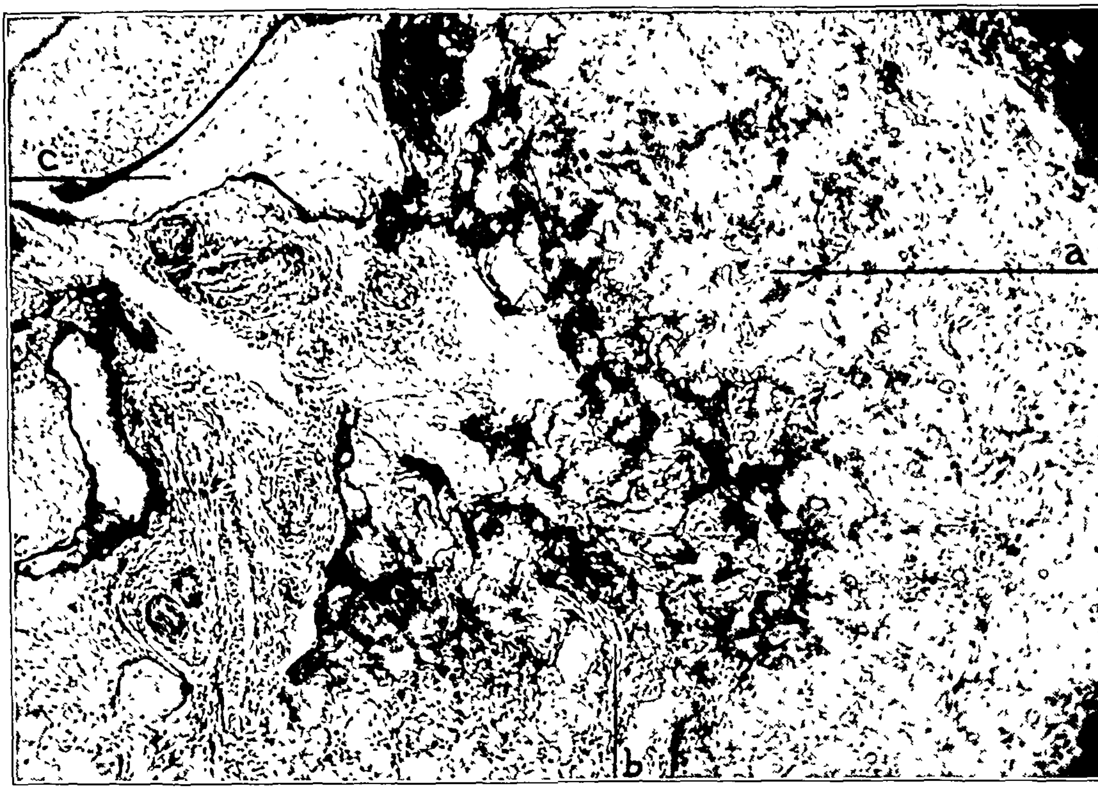

Fig. 1-D

Photomicrograph (× 96) of the edge of the lesion shows irregularly calcified osteoid tissue *a*; vascular fibrous stroma *b*; and normal regional bone *c*.

Fig. 1-E

Photomicrograph (× 112) showing marked degeneration of the articular cartilage of the femoral head. The oblique split is an artifact.

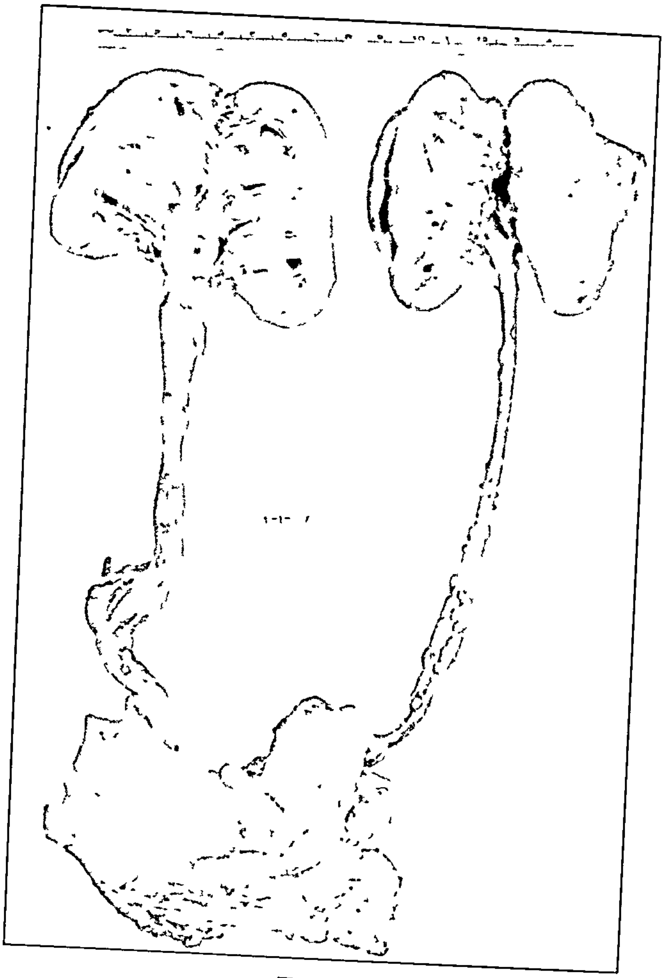

Fig. 2

Fig. 3

Fig. 2: The discrete, globular, thin-walled cysts along the ureters are shown. No cysts were found in the bladder. Note the small, contracted, finely granular kidneys. Microscopically, a very small amount of functioning kidney tissue remained.

Fig. 3: Longitudinal section of spine between the fourth and eleventh thoracic vertebrae, showing the great narrowing of vertebral bodies with almost complete collapse of two of them, and the secondary expansion of the intervertebral discs. The brown material in the center of the vertebral bodies (see arrow) was soft and gritty, and on microscopic examination proved to be hyperplastic bone marrow with degenerated trabeculae scattered throughout. The cortical bone of the spinous processes was still hard, and fairly dense.

consolidation were present bilaterally. The kidneys were unusually small and soft, with finely granular, pitted surfaces. Their cut surfaces showed marked loss of substance, with practically no cortical tissue recognizable grossly. The renal pelves were not dilated, but the ureters presented remarkable changes in that discrete, globular, thin-walled, clear cysts studded the upper three-fourths of the mucosal surfaces of each. The cystic structures averaged one to two millimeters in diameter, and when pricked, collapsed completely, liberating a small quantity of clear fluid. The lining of the ureters between the cysts had the usual gray, velvety appearance. The cysts were clustered, so that each one touched another on several sides. Despite this, the ureters appeared little dilated, if at all. The urinary bladder was contracted and thick-walled, but the mucosal surface was free of cysts (Fig. 2). The gall bladder was extremely contracted. The spleen was atrophic, with numerous irregular, gritty, yellowish masses scattered throughout the pulp. The liver was brown and shrunken, and contained several firm nodules just under the capsule. A single calcified plaque, about 0.5 centimeter in diameter, was found in the wall of the stomach. The genitalia presented the usual appearance of senile atrophy. Nothing else unusual was noted about the viscera.

Grossly, the bones were soft. The ribs, on cross section, showed extreme thinning of the cortex with much loss of trabecular pattern and many cystic dilations in the medullary portion. Little marrow or fat was present. There was a severe kyphosis in the upper thoracic spine, with complete collapse of the bodies of the fifth and eighth thoracic vertebrae. The centra of all the thoracic and lumbar vertebrae were narrowed and extremely fragile. The spine between the fourth and twelfth thoracic vertebrae was removed in one piece for further examination. The photograph of the sawed specimen (Fig. 3) shows the great narrowing of two of the vertebral bodies. The bodies of nearly all the vertebrae consisted of thin shells of cortical bone, their central portions being almost completely replaced by a soft, mushy,

rate was now normal. The elbow, restricted in motion to about 60 degrees of flexion and extension, was markedly swollen and warm. There was generalized pain on motion and exquisite tenderness over the head of the radius.

A course of treatment with penicillin and one with the sulfonamides made no difference in the symptoms or findings. Therefore, with a provisional diagnosis of osteochondritis dissecans or osteoid osteoma, the elbow was explored through a posterior incision[8]. The site of the olecranon fossa was completely occupied by a purplish cribriform bone, which was sharply delimited from the rest of the humerus. This bone was completely removed. Biopsy sections were taken from the synovial membrane, which was injected and thickened. Inspection of the joint surfaces revealed nothing otherwise abnormal, so the wound was closed. Figure 2-C shows the findings of the roentgenograms after operation.

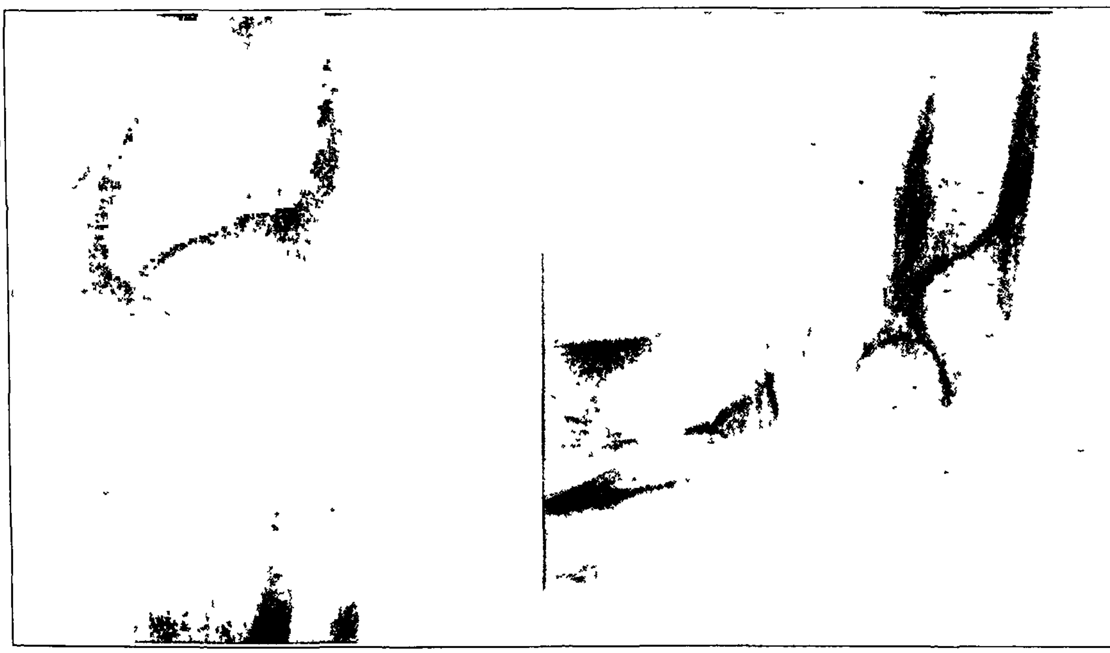

FIG. 2-A

Case 2. Initial roentgenogram. Note the shadow of periosteal new bone about the lower humerus and irregularity of the ossification center of the trochlea but no pathognomonic changes.

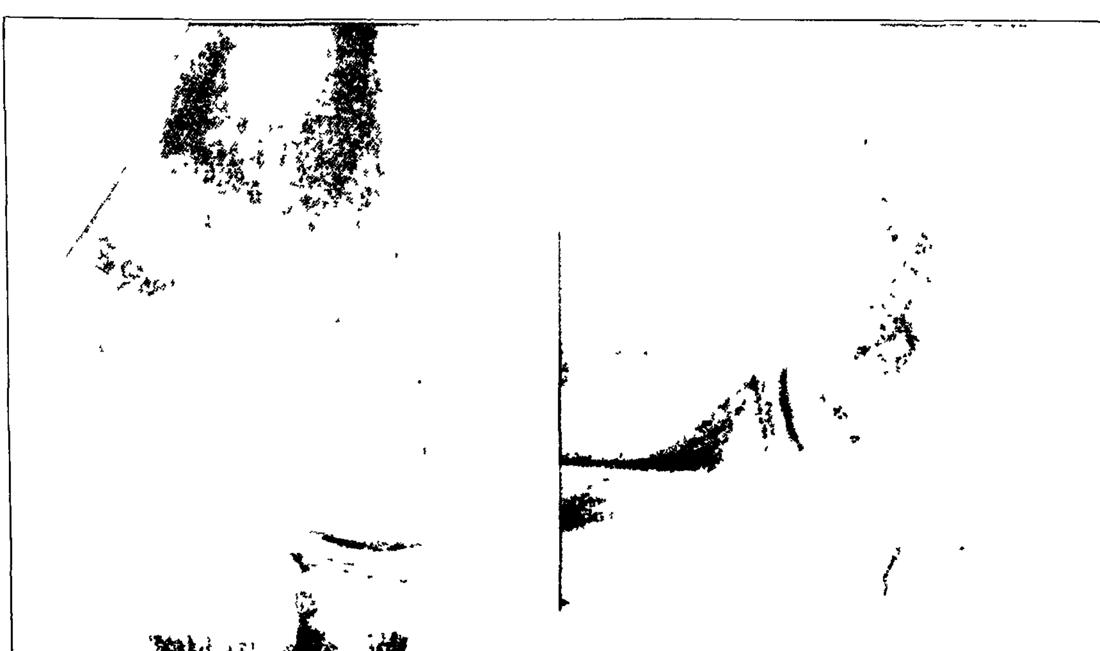

FIG. 2-B

Seven months later there is an obvious lesion in the olecranon fossa. The area is radiolucent except for the center which is irregularly dense. There is gross thickening of the entire lower end of the humerus.

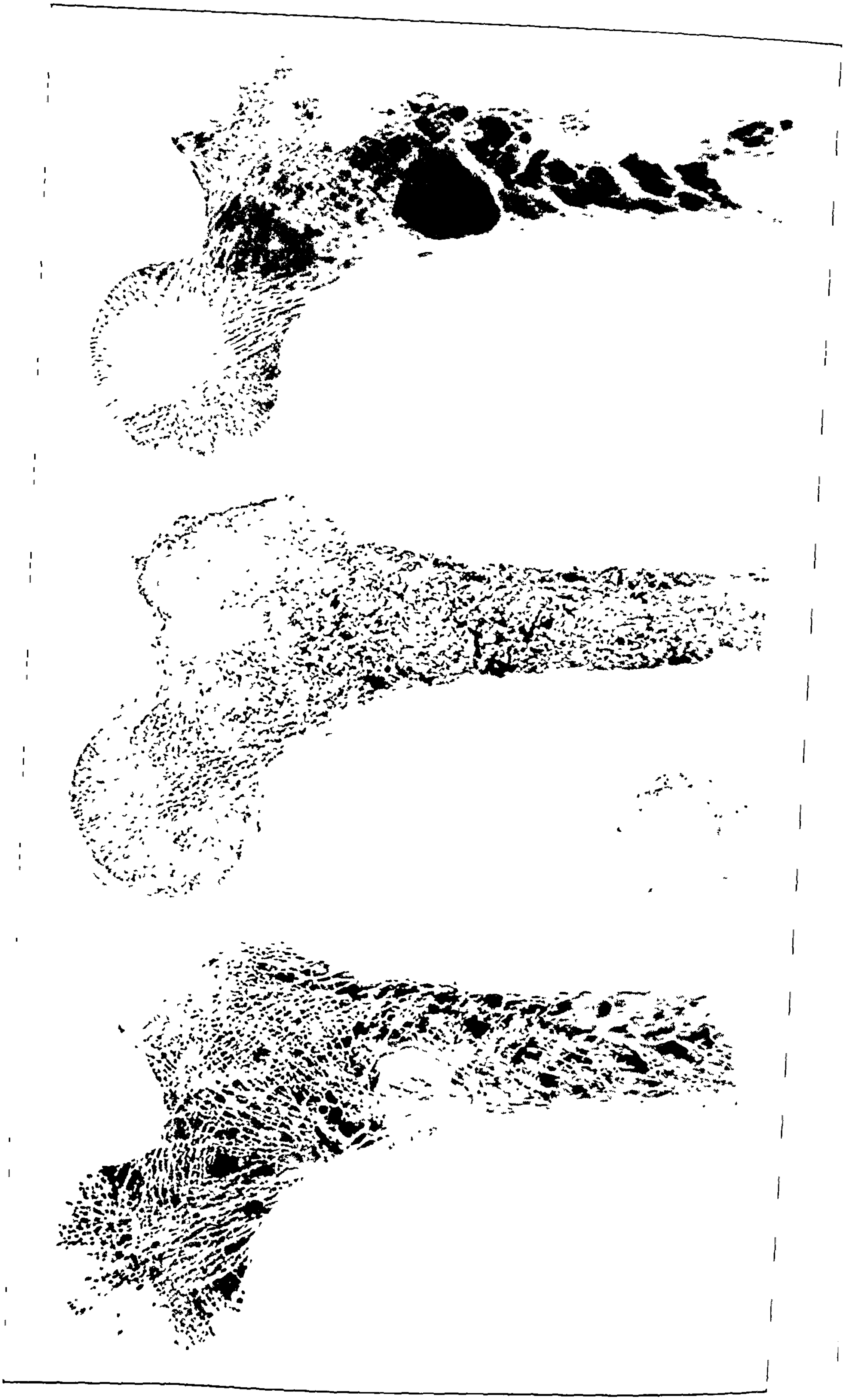

Fig. 4

(*A*) Roentgenogram of sawed specimen of femur. (*B*) Longitudinal section of the fresh specimen, proving that the rarefied areas in the roentgenogram actually were filled with tissue, there being no true cysts

proliferation, dilatation of blood vessels, intense infiltration with small round cells, and fibrin deposition on the surface (Fig. 2-F).

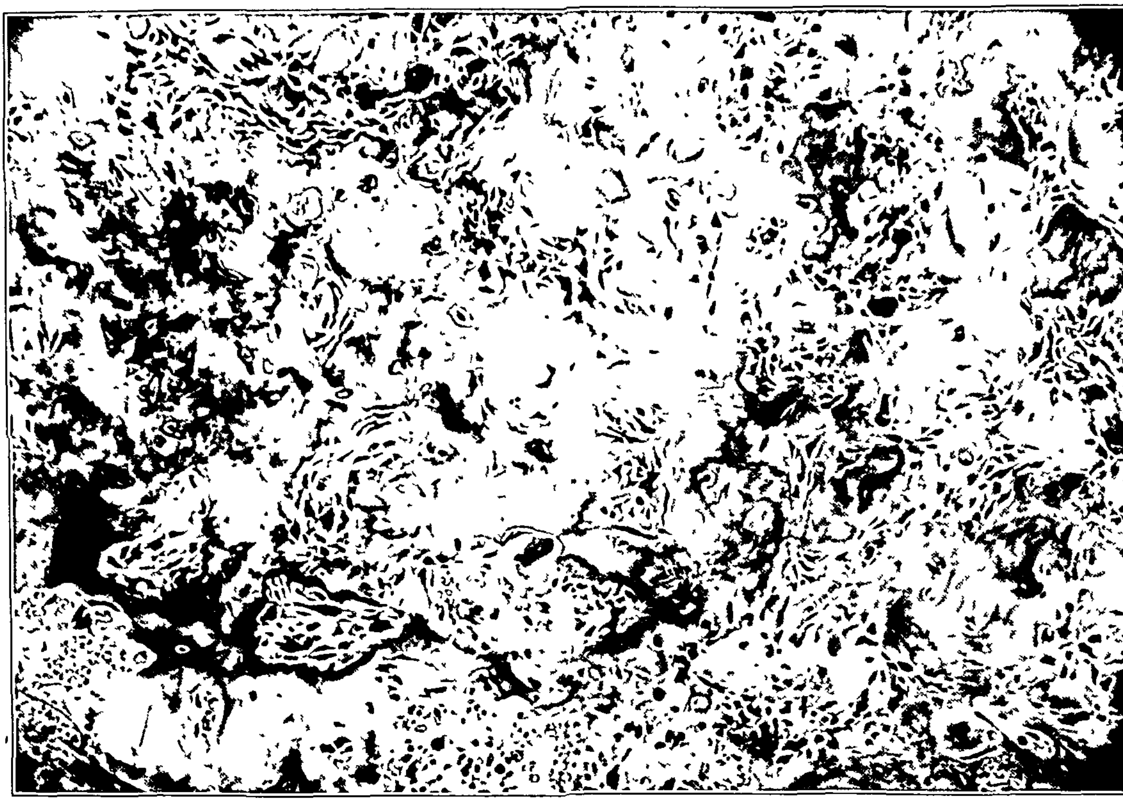

Fig 2-E
High-power photomicrograph (× 180) shows fibrous stroma with many osteoblasts and osteoclasts, and partially calcified masses of osteoid.

Fig. 2-F
Photomicrograph (× 90) of synovial membrane showing chronic inflammatory reaction.

mentioned briefly. Bergstrand noted lacunar resorption and slight osteitis fibrosa in patients dying of chronic glomerulonephritis. Follis and Jackson found evidence of microscopic bone changes, which they considered as both osteitis fibrosa and as osteomalacia, in about half of a series of routine autopsies in cases of renal insufficiency. Ginzler and Jaffe found evidence of osteitis fibrosa of varying degrees in instances of chronic renal insufficiency, and indicated that, if the lesions were to be found at all, they were present in the trabeculae of the vertebral bodies. While the final pathological result of hyperparathyroidism as regards bone has been well described[17] and is well known, the less advanced stages, such as those described by Bergstrand, apparently are less generally recognized. The primary features of osteitis fibrosa, as described by Jaffe and his associates[17,19] from clinical and experimental material, consist of generalized resorption of bone and enlargement of the canals of blood vessels; numerous Howship's lacunae and osteoclasts on the surfaces of the trabeculae, under the endosteum and periosteum, and on the walls of the canals of the blood

FIG. 5-A

FIG. 5-B

RENAL OSTEITIS FIBROSA SUPERIMPOSED ON SENILE OSTEOPOROSIS

Report of a Case Without Parathyroid Hyperplasia and With Ureteritis Cystica

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It is now well known that extensive bone changes may occur in children with chronic renal insufficiency. That a syndrome comparable to renal rickets occurs in adults has been recognized less frequently, although an increasing number of cases have been reported since Albright, Drake, and Sulkowitch called attention to the condition in 1937. The advanced cases in adults remain a rarity, even though it has been shown that microscopic bone changes commonly are associated with renal insufficiency[4,11,14]. Parathyroid hyperplasia has been found in nearly every case in which the parathyroid glands were examined, both in children and adults. Even in the absence of osseous changes, parathyroid hyperplasia has been demonstrated in many cases of chronic renal insufficiency; and apparently it has also been induced by experimental renal insufficiency[10,16,21] and in other ways. Indeed, the most widely accepted name for the syndrome is "renal hyperparathyroidism". Only a few instances have been reported in which the parathyroids were described as not being enlarged. No case report has been found in which the condition occurred in senility; in fact, the number of patients over thirty years of age is limited. The oldest examples previously recorded are a patient of Brown and Ginsburg's, aged fifty-five, and Gutman, Swenson, and Parson's fourth case, a woman of sixty. The latter case has certain similarities to the one to be presented.

The purpose of this paper is to describe a senile patient with renal insufficiency and roentgenographic findings suggestive of hyperparathyroidism, but with different findings at autopsy.

CASE REPORT

History

Mrs. E. M., a white woman, seventy-five years old, first came under observation in September 1939, when she appeared at the Out-Patient Clinic, complaining of general fatigability which had come on gradually over the preceding two years. Her only other complaints were of slight incontinence of urine at times, and occasional nausea, caused by stooping or a sudden change of position. She was moderately obese; her systolic blood pressure was 198 millimeters of mercury, diastolic 94 millimeters. A mild degree of scoliosis of the thoracic spine was noted, but otherwise the osseous system attracted no attention at the time. The heart was not enlarged, and only the right radial artery felt sclerotic. Urinalysis disclosed the presence of albumin (one plus), pus (one plus), and bacteria (one plus) in the centrifuged sediment. The sedimentation rate of the erythrocytes (modified Westergren method) was 4 millimeters in fifteen minutes and 30 millimeters in forty-five minutes (normals are 0 to 5 millimeters in fifteen minutes and 0 to 30 millimeters in forty-five minutes). The basal metabolic rate was reported as minus 5 per cent. The patient's condition was followed for about ten months, during which period there was little change. In June 1940, she complained of the sudden onset of pain over the radial surface of the left wrist, for which she received local treatment, but roentgenograms were not made.

She was not seen again until December 10, 1945, at which time she was admitted to the hospital because of pain in the right hip, resulting from a fall sustained four days before in her bedroom. She stated that she had felt pretty well from the time she was last seen (June 1940) until 1942, when pain began in the lower thoracic vertebrae and in the index and middle fingers of the right hand, radiating upward along the radius to a point about eight centimeters above the wrist. This pain had persisted in spite of treatment. In June 1945, she began having dyspnoea, and in November there was an episode of nausea and vomiting which lasted fifteen days. The hip became gradually worse from the time of her fall on December 6 until admission four days later, and pain in the other bones of the lower extremities was present as well.

Physical Examination

Physical examination at this time showed a considerable degree of weight loss since examination. The systolic blood pressure was 94 millimeters of mercury, and the diastol'

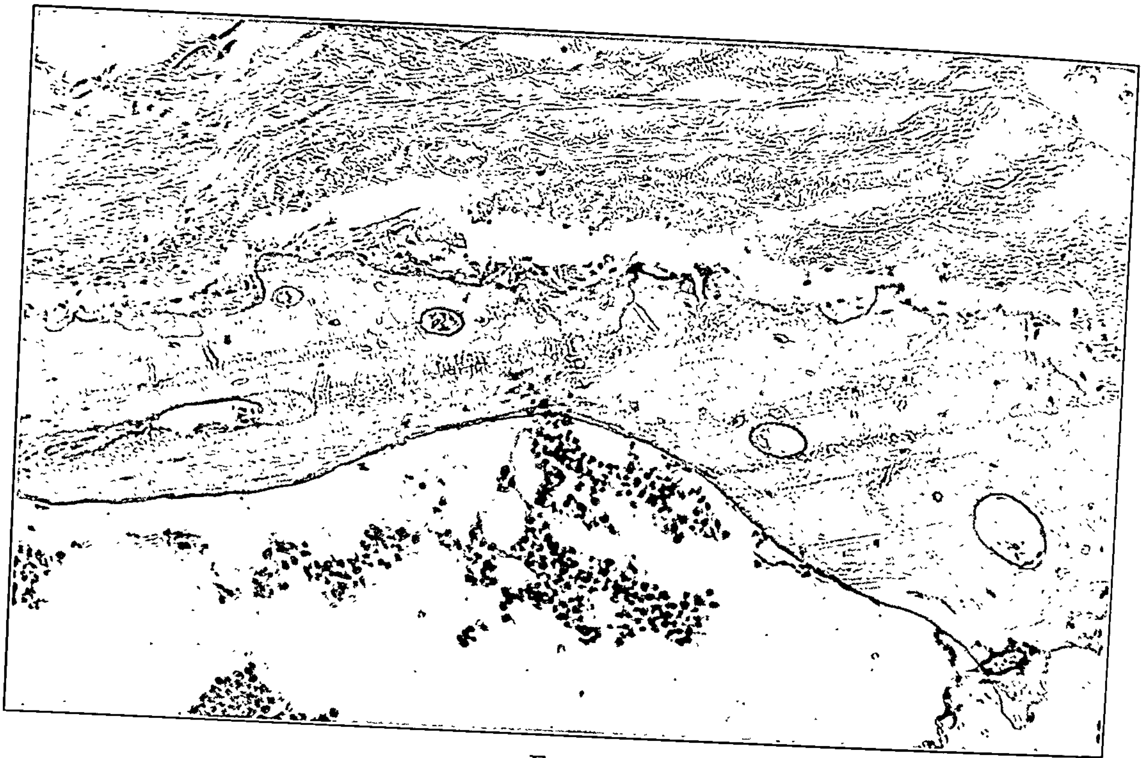

FIG. 6

Photomicrograph of portion of rib, displaying the thin cortex and serrated subperiosteal surface (× 132).

FIG. 7

Photomicrograph of a portion of vertebral body, showing (*a*) osteoclastic resorption of bone; (*b*) fibrous replacement of marrow, near which are two spicules of bone, showing both bone production and osteoclastic resorption; and (*c*) uninvolved bone marrow (× 150).

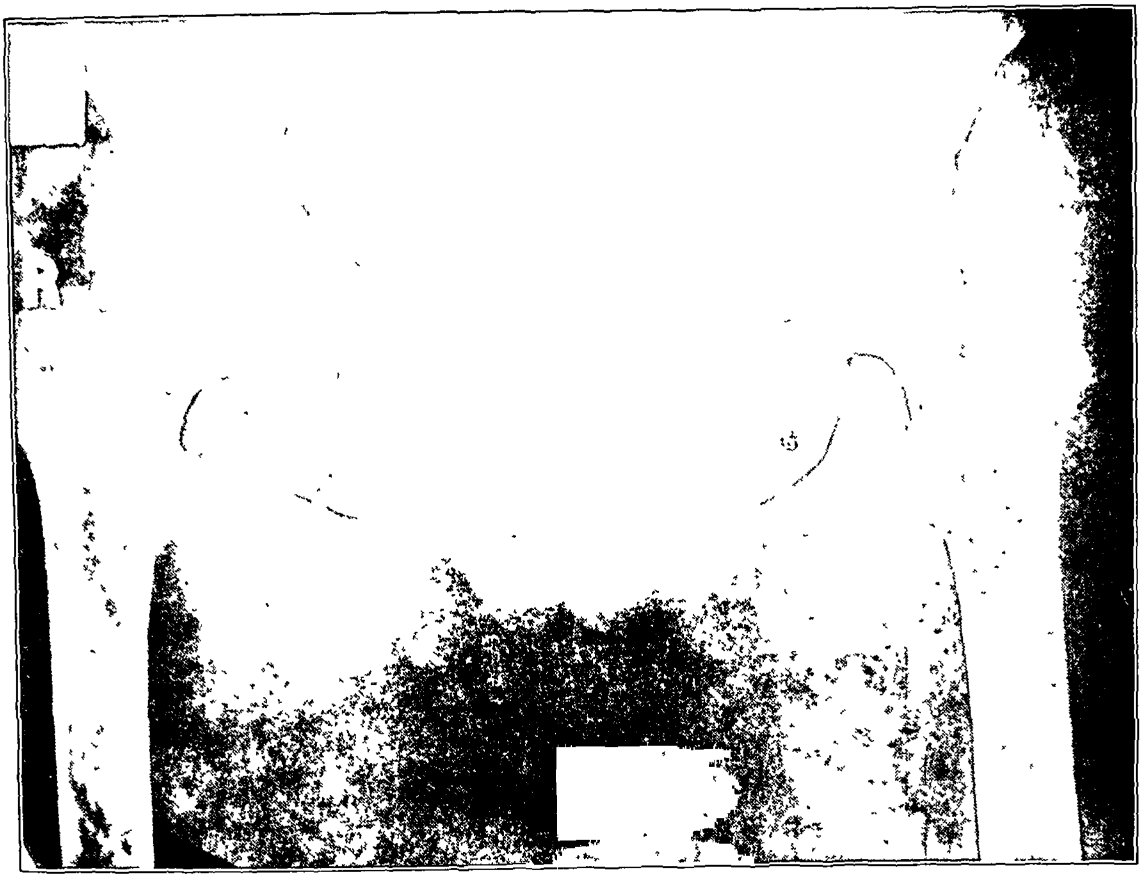

FIG. 1-C

1-B, and 1-C). There was extreme rarefaction of the spine, with evidence of collapse of several of the vertebral bodies. The skull displayed several discrete rounded areas of rarefaction. Together, these findings were considered characteristic of the bone changes of hyperparathyroidism.

Laboratory Data

The urine gave a positive test for albumin (one plus), and contained pus (one plus) and bacteria. The specific gravity was consistently low,—around 1.007. Subsequent examinations yielded essentially similar results, but with more pus cells on several occasions. A strain of *Escherichia coli* was isolated on one culture. The red-blood-cell count was 3,500,000 per cubic millimeter, and the hemoglobin was 10.0 grams per 100 cubic centimeters. The white-blood-cell count was 10,500 per cubic millimeter on admission, climbing to 25,200 on the day before death. A relatively high percentage of staff cells were noted, but otherwise the blood smears showed nothing unusual. The erythrocyte sedimentation rate was two millimeters in fifteen minutes and seventeen millimeters in forty-five minutes at the time of admission; it was considerably higher later, amounting to forty-one millimeters in the first fifteen minutes on December 22. The serological tests for syphilis were consistently negative. A sternal-marrow cell count and differential smear on December 28 were not significantly deviated from normal. The inorganic-phosphorus level in the fasting serum was 10.4 milligrams per 100 cubic centimeters on December 18, and the serum calcium was 9.4 milligrams per 100 cubic centimeters. On the day before death the value for phosphorus was 10.4 milligrams and that for calcium was 7.4 milligrams per 100 cubic centimeters. The urea nitrogen was 152 milligrams per 100 cubic centimeters of whole blood on admission, and remained at about that level on three other examinations. The alkali reserve was forty on December 26, declined to thirty-six two days later, and was thirty-one on the day prior to death, indicating persistent acidosis.

The patient's condition was poor at all times. She continued to complain of pain in her bones. The course was rapidly downward, with death from uraemia on January 1, 1946.

Autopsy Findings

The body was emaciated. The ribs were soft enough to be cut readily with a knife. The heart appeared to be little enlarged, and weighed 250 grams. The ring of the mitral valve was calcified, but the valve itself was competent. The coronary arteries were moderately sclerotic. The aorta showed a moderate degree of atherosclerosis with calcification of many of the plaques, but the condition was not inconsistent with the subject's age. The lungs were bound down by fibrous adhesions. Patchy areas of

which the parathyroids were identified, the presence of parathyroid hyperplasia, usually recognized easily on gross examination, has been stressed. A fairly extensive search of the literature has failed to reveal other cases of renal osteodystrophy in which all the parathyroids were identified and found not enlarged. The present case is exceptional in this respect, but it must be admitted that the degree of skeletal involvement secondary to the renal disease is problematic; and perhaps, had the patient lived longer with renal insufficiency, parathyroid hyperplasia might have become manifest.

Ureters

Although ureteritis cystica of the extent found in this case is not frequently seen, lesser degrees are evidently more common than is generally realized. Morse found sixty cases, and studied 125 routine autopsy specimens, in 86 per cent. of which he found microscopic evidence of epithelial-cell nests and cysts in the urinary tract. He offered evidence of an inflammatory origin for the cysts, and demonstrated stages in their development from the epithelial-cell nests of von Brunn to the thin-walled, macroscopic cysts. Kindall, Toulson, Bothe and Cristol, and others have since added confirmatory evidence to this theory of pathogenesis, and it now seems well established that ureteritis cystica is a pathological entity related to chronic inflammation.

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granular tissue which could easily be scooped out. The residual cancellous bone of the centra was scanty, and the trabeculae were extraordinarily delicate. The upper fourth of the left femur was removed. The shaft offered much less than normal resistance to cutting, because of thinning of the cortex, but was still hard enough to require the use of a chisel. The sawed specimen is shown in Figure 4. No true cysts were present, but several areas in the neck and proximal portion of the shaft were soft, and cancellous bone was replaced by a spongy, red, somewhat granular mass of tissue which could be scooped out; this left an irregular depression in the bone where trabeculae were missing, just as in the vertebrae. These were the areas which appeared cystic in the roentgenogram. The cortex was thin, with numerous ovoid erosions on the endosteal surface, corresponding to the rounded radiolucent areas noted in the roentgenogram. The extreme atrophy of cortical bone is especially apparent when a cross section of the femur from this case is compared with one from the same level in another patient of the same age whose bones were not rarefied (Fig. 4, *D*). The trabecular pattern of the head of the femur showed little change, except for atrophy of the trabeculae, in the interstices of which fatty marrow could be seen. The macerated specimen exhibited a hollow area in the neck of the femur and another in the subtrochanteric region,—areas in which soft tissue had completely replaced the cancellous bone. The cortex adjacent to these areas was paper thin. The calvarium was thin, but fairly well calcified. The rarefied areas noted in the roentgenogram were visible on the undersurface as thin, bluish, slightly elevated, round areas. A thin layer of bone covered them, and they contained some of the soft, pulpy tissue, similar to that in the vertebrae and femur, which replaced the bone. Nothing unusual was noted about the brain, pineal gland, or pituitary. The base of the skull appeared well calcified.

The thyroid gland was small and somewhat nodular. The parathyroid glands were not identified with certainty on the gross specimen. A single nodule, 1.5 centimeters in length, was found embedded on the posterior portion of the thyroid, in the capsule; but this proved to be thyroid tissue. A number of small, brownish, oval masses, none of which was over 0.5 centimeter in length, were found in the regions where the parathyroids should be situated; all of these were saved for microscopic examination. In addition, the entire posterior and lateral surfaces of the thyroid, including the capsule and a thin layer of thyroid tissue, were sliced off and embedded. The entire thyroid gland was then sectioned at three-millimeter intervals. There was little fat on the neck organs, and it was felt that all tissue which could even remotely be considered parathyroid was saved for study. Out of all this, four distinct parathyroid glands were identified.

Histological Examination of Parathyroid Glands (Figs. 5-A, 5-B, 5-C, and 5-D)

Multiple sections were made of each of the four glands identified, and the largest one was serially sectioned. The largest portion of each of the glands was measured in the paraffin blocks, as follows: The first was 8.5 by 3.5 millimeters (serial sections proved this gland to be less than 0.3 millimeter in thickness); the others measured 3 by 3 by 3 millimeters, 5 by 2.5 millimeters, and 4.5 by 2 millimeters, respectively. (The last two glands were not more than 1 millimeter in thickness.)

The glands did not have a uniform structure. Each contained a moderate amount of fat. The stroma was thickened and hyalinized in all the glands, but to a much more marked degree in two of them. The cells were arranged for the most part in anastomosing cords and in irregular sheets, with very little tendency for pseudo-acinous formation. Chief cells predominated, a few sharply demarcated islands of dark oxyphil cells being present, with a greater percentage of the oxyphil cells in the largest gland. These islets were fairly large in some areas. One of the glands appeared completely atrophic, with extreme hyalinization replacing much of the glandular substance; the few remaining cells were vacuolated. The hyaline material was suggestive enough of amyloid so that Congo red, crystal violet, and van Gieson's stains were applied, without evidence of amyloid being obtained. There was no evidence of hyperplasia of any of the parathyroid glands, and this was further ruled out by attempting to apply the criteria of Castleman and Mallory for parathyroid hyperplasia, with negative results.

Bones

Portions taken from several vertebrae, ribs, the head and the proximal shaft of the femur, and the skull, were decalcified in formic acid, and stained with hematoxylin and eosin. Although the findings varied, the over-all picture was that of marked atrophy with slight, but definite, osteitis fibrosa. Atrophy, or senile osteoporosis, was manifested by extreme thinning of the cortical bone of the vertebral bodies, ribs, and femur; narrowing and decrease in the number of the trabeculae; and widening of the Haversian canals without very much fibrous-tissue invasion. The extent of bone production appeared limited, but osteoid seams were narrow, and that bone which was being laid down evidently was being calcified. In the head of the femur, cortical bone was deficient in many areas, trabeculae joining articular cartilage directly. The plates of cortical bone of the vertebral centra were similarly affected, so that it was difficult in many areas to find any zone of osseous tissue between the cartilage of the intervertebral discs and the thin trabeculae of the spongiosa. Other changes, however, complicated this picture.

The ribs showed extensive subperiosteal erosions, so that their outer surfaces were serrated by irregular, somewhat lacunar, areas of resorption, which were filled by fibrous tissue of the periosteum

In addition to adding to the reported incidence of renal rickets, the justification for presenting this case might be considered as threefold: First, from the standpoint of history, physical examination, laboratory findings, and clinical course, the case presents a consistently typical and gross picture of the disease entity in question. Second, strong evidence is provided that, depending upon the exact location of the pathological condition in the genito-urinary tract, therapy may prove quite efficacious. Third, it indicates the necessity for a complete urological investigation of every case of rickets at an early date, in order that medical measures can be instituted to greater effect and unwise surgical intervention be avoided.

The syndrome of renal rickets is of comparatively recent recognition. A review of its history reveals that the association of rickets with albuminuria was made by Lucas as late as 1883, and it was not until 1911 that renal insufficiency was recognized as the occasional cause of rickets by Fletcher and Parsons. It remained for Barber, in 1921, to define the condition.

For the etiology of renal rickets and the explanation of the pathological physiology involved, we are indebted to Mitchell, who, in 1930, provided us with the hypothesis which has subsequently been verified scientifically. Briefly, this has consisted in the demonstration that, with diminished urinary excretion, there is a retention of phosphates; the phosphates thus retained are excreted into the lumen of the intestine in an attempt on the part of the body to make physiological compensation, and in the intestine they form insoluble compounds with whatever calcium has been ingested. This fact is substantiated by the consistently elevated calcium content of the faeces in such cases, and, incidentally, shows the futility of the oral administration of calcium. Further, it explains the invariable occurrence of a high serum phosphorus and a low serum calcium in the laboratory examination[1,3].

Anything capable of producing a diminished urinary excretion, extending over a prolonged course, during the growth period is capable of producing renal rickets. Thus the possible sources of etiology are as varied as the components of the renal system and the many types of pathological changes to which each is heir. Some, such as congenital anomalies involving the ureterocystic orifices, are remediable; others, such as chronic glomerulonephritis, may be irreversible. A prognosis should not be given or the case despaired of without a careful analysis and evaluation of the entire renal system. Only after such an investigation was the outlook in the case to be described determined to be hopeless[4,5,7,8].

CASE REPORT

Clinical History

The patient was a white girl, fourteen years of age, with the chief complaint of a progressive, bilateral knock-knee deformity and weakness of only six months' duration, for which she made application to the Orthopaedic Dispensary of the Illinois Research and Educational Hospital. Admission to the Hospital followed, on September 9, 1943, in order to complete the investigation. A more detailed history disclosed that, in addition to the obvious progressive fatigue and increasing genu valgum deformity of six months' duration, the patient had recently complained of a mild aching in the calf muscles and in the knees; this was aggravated by walking distances of one block or more. The mother provided the information that the patient had had pyelitis at the age of two with at least two or three exacerbations of chills and fever during subsequent years, but the local physician had said she had recovered. Her general nutrition and body growth had obviously been poor for the past three or four years. The mother stated that the child's early diet had been adequate in all respects, particularly as regards cod-liver oil. The regimen was described and seemed sufficient. The mother stated further that the same quantities had been administered to the patient's younger sister, who was now ten years old and larger than the patient.

When the patient's present symptoms began, an orthopaedic surgeon in an adjacent state was consulted, and the patient was advised to make arrangements for supracondylar osteotomies to be done. The seriousness of the condition had been minimized; and a good prognosis had been rendered. The family had refused surgery at that time, however.

FIG. 4 (*continued*)

Note the lacunae-like erosions of the endosteal surfaces in the roentgenogram and gross specimen. (*C*) Macerated bone, showing loss of trabeculae in the cystic areas, extreme thinning of the cortex, and unusual delicacy of the trabecular pattern. The inset (*D*) strikingly compares a cross section of half of the shaft of the femur in the case under discussion with a section from a corresponding area, taken from another woman of seventy-five, whose bones appeared normal by roentgenogram.

(Fig. 6). Similar rough, saw-tooth-like edges, varying in degree, were noted on the subperiosteal surfaces of all bones examined. In some areas, mononuclear cells seemed to be producing these erosions, but this finding was inconstant. Multinucleated cells were not found on the outer surfaces of the cortex. The endosteal surfaces were similarly eroded in many areas, smooth in others. Multinucleated cells were found in some of these areas, which had the appearance of typical Howship's lacunae. Some of the trabeculae of the spongiosa of the ribs, vertebrae, and femur showed such lacunar resorption as well, but in only a few areas was it well marked. There was quantitatively little marrow fibrosis. In most areas, the marrow was quite cellular,—even hyperplastic. The soft, friable tissue, which occupied the spaces which appeared cystic in the roentgenograms of the skull and femur, proved to be bone marrow with less fat than usual. (Some of this material was stained with Ehrlich's trichrome stain to help differentiate the cell types. All the usual marrow elements were present, with a tendency toward an erythroblastic reaction.) Definite osteitis fibrosa was noted in several vertebral bodies, including a collapsed one. In these areas, osteoclasts were numerous, lying in Howship's lacunae; young fibrous tissue replaced the marrow locally, and extended into the bone in the areas of resorption; and spicules of new bone were seen in this fibrous tissue, surrounded by single layers of osteoblasts (Fig. 7). Finally, fibrous tissue from the marrow penetrated the bases of some of the original trabeculae. In some instances, this appearance was noted in the bone, but only marrow cells with little fibrous tissue could be seen in the erosion. Such areas were thought to represent the earliest stages of "dissecting bone resorption"[17].

Kidneys

Few functioning glomeruli remained; the majority of them were hyalinized. There was much interstitial fibrosis, in the form of thick bands of collagen, with numerous areas of lymphocytic infiltration throughout. The tubules showed evidence of degeneration of epithelium, to a large extent. Many of the collecting tubules were filled with clumps of polymorphonuclear leukocytes. Marked arteriosclerosis was present throughout. The pelvis was thickened, and pus was present in the lumen.

Ureters

The cysts were large and thin-walled, formed of a thin layer of flat cells, and were filled with a colloid material.

Bladder

The epithelium was thickened, and chronic ulcerative inflammatory changes were present. The vessels of the submucosa were largely hyalinized. Cystic epithelial nests were noted in the submucosa (von Brunn inclusion cysts).

Other Organs

Large rounded areas of hyalinization were noted in the spleen, which also showed considerable atrophy. The cardiac muscle showed brown atrophy, with pronounced subintimal thickening of the smaller arteries and arterioles. Advanced arteriosclerotic changes were noted in the vessels of the lungs, together with patchy acute bronchopneumonia and hyperaemia. The liver showed mild chronic passive congestion, slight biliary retention, and several areas of focal necrosis with calcification. There was nodular adenomatous hyperplasia of the thyroid, and several of the larger arteries showed calcification of the media. Parenchymal changes, consistent with the age of the subject, were evident in the remaining organs, with an unusual degree of hyalinization of the smaller arteries and arterioles.

DISCUSSION

The first question that arose was whether the bone lesions in this case should be designated as osteitis fibrosa, or whether the rarefaction was due entirely to senile osteoporosis and the renal findings were merely coincidental. On reviewing the literature of renal osteodystrophy, the following facts seemed important: The bone changes in renal osteitis fibrosa in the adult are usually considered indistinguishable from those seen in patients with osteitis fibrosa generalisata due to primary hyperparathyroidism[2,31]. Even in children, renal rickets is not really rickets histologically, but is often osteitis fibrosa[6,25]. Cases have been reported in which the bone changes were not designated osteitis fibrosa[7,23,26], but in most of these cases the bones have not been studied thoroughly, or at least are only

During the hospital course, which extended from September 9, 1943, until the patient's death on December 21, 1943, there was a progressively severe nitrogenous retention, as evidenced by blood-chemistry findings. On December 8, the non-protein nitrogen was 320 milligrams, urea nitrogen 180 milligrams, uric acid 14.8 milligrams, and creatinine 16.6 milligrams per 100 cubic centimeters of blood. By this time a complete reversal of the calcium-phosphorus ratio had occurred, the serum-calcium level being 4.5 milligrams and the phosphorus level 8.7 milligrams per 100 cubic centimeters of blood. Up to

FIG. 2-A

FIG. 2-B

Anteroposterior and lateral views of the knees, demonstrating fuzziness and irregularity in the area of the epiphyseal plates, and indicating activity in the rachitic process.

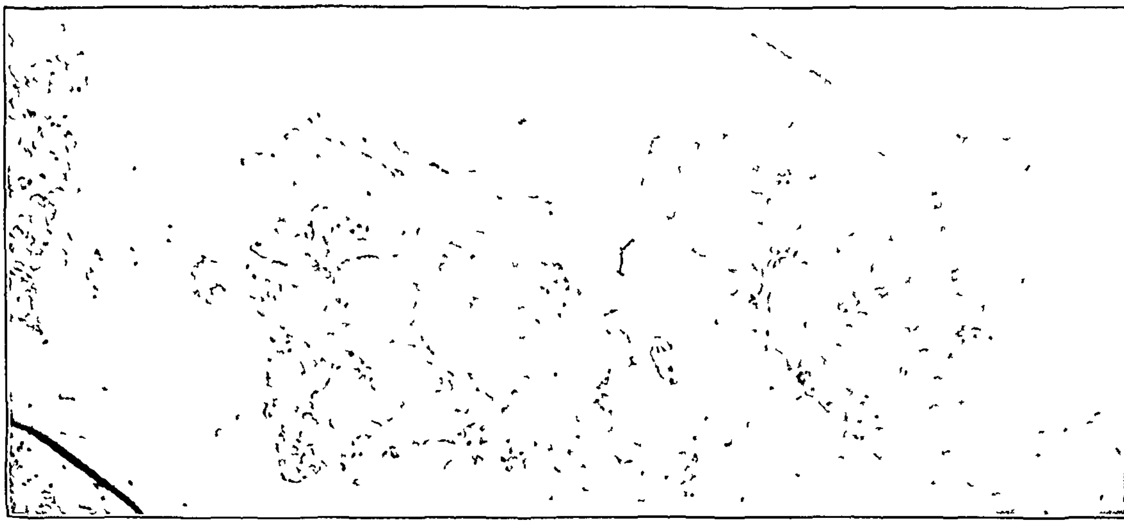

Fig 5-C

Fig. 5-A, Fig. 5-B, and Fig 5-C: Low-power photomicrographs (× 15) of entire glands of each of the four parathyroid glands discovered. The gland shown at the right of Fig 5-A was atrophied.

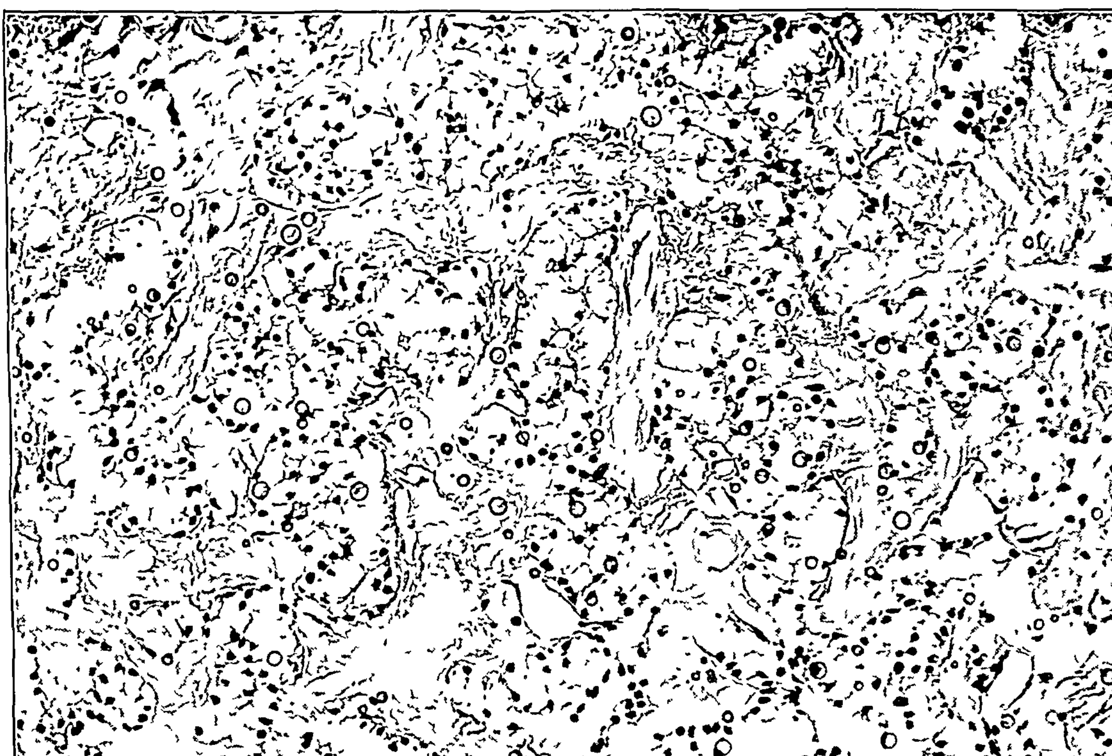

Fig. 5-D

A higher-power photomicrograph (× 150) of the gland at the right of Fig. 5-A, showing the thick strands of hyaline and the atrophic cells.

vessels; scarring of the bone marrow; and formation of some trabeculae of new bone in the fibrous tissue. Osteoid tissue is not necessarily present. These represent the fundamental changes. In any particular case they may be modified by a number of other factors, such as the age and state of nutrition of the patient, the condition of the parathyroid glands, the state of the renal function, the calcium balance, and even the rate of decalcification[20]. The interpretation of the osseous changes in any particular case must take such factors into consideration. On the basis of accumulated evidence, it seems logical at present to assume that, when there is evidence of *chronic renal insufficiency in the absence of primary para-*

the last, the total urinary output daily averaged about 2000 cubic centimeters, but this was of low specific gravity.

The patient's clinical course was one of progressively increasing weakness. On November 30 she became confined to bed because of weakness and pain in the knees, and on that day had a rather severe epistaxis which required nasal packs. On December 4 the patient experienced two convulsive seizures with clonic contractures of all extremities, lasting only about one minute in each instance. Following this, she complained of diplopia the remainder of the day. She felt somewhat better during the next few days, but on December 11 complained of sudden precordial pain; dyspnoea and apprehension were apparent, but no cyanosis; she was orthopneic, and the next day a marked precordial friction rub could be heard. However, by this time the patient was much more comfortable, and less orthopneic and apprehensive. This improvement was probably on the basis of a resorption of pericardial effusion. A subsequent electrocardiogram was consistent with uraemic pericarditis.

On December 14 a generalized follicular eruption appeared, consisting of pinhead-sized non-inflammatory papules, with horny spines projecting from the follicles. This was considered by the Department of Dermatology to be due to a vitamin-A deficiency. On December 16 gross evidence of cardiac failure was present, with swelling of the face and neck, jugular distention, and marked epigastric tenderness. The liver was palpable 3.5 centimeters below the costal margin; an abdominal fluid wave could be elicited. Râles were noted over the bases of the lungs; cardiac enlargement, both to the right and left, was demonstrable; and death was apparently on the basis of cardiac failure, occurring during the terminal uraemia.

At autopsy the essential renal findings were those of a congenital hypoplasia of the right kidney with stricture of the ureter, and a very marked chronic pyelonephritis on the left with gross destruction of the parenchyma. The parathyroids were hyperplastic.

Therapy in this case was of a supportive nature only, as the renal status and its absolute irreversibility were appreciated early in the hospital course. Oral administration of calcium has long been known to be futile, as absorption from the intestinal tract fails to occur; parenteral calcium has yielded as little therapeutic result and has actually been considered contra-indicated, because of the vicarious calcification of tissues which has been observed. Only if some correctable source of the nitrogenous retention, such as an uncomplicated ureteral stricture, had been discovered, could therapy have had a curative effect.

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thyroid disorder, histological signs of osteitis fibrosa, however slight, are attributable to the kidney disease. In this case, the primary features of osteitis fibrosa are found, but they are of limited extent; and it is difficult to attribute the advanced state of rarefaction of the skeleton to this finding alone. There is insufficient connective tissue in the Haversian canals and about the bone trabeculae. Osteoclastic resorption is not extensive enough. There is too little new-bone formation, and marrow fibrosis is almost non-existent.

In senile osteoporosis, the pure lesion has been described by Jaffe as a chronic fatty atrophy of bone, with thinning of trabeculae and cortex, widened vascular canals, negligible lacunar resorption, and a smooth periosteal surface of the cortex. Osteoid borders are not demonstrable. Fibrous transformation of the marrow may occur in areas in which there has been collapse of the spongy bone, such as the weakened vertebral bodies. Rarely, advanced cases of senile osteoporosis have been reported in which decalcification was so marked that the roentgenographic examination was suggestive of hyperparathyroidism[12]. Such changes characterize this case, and, in all probability, senile osteoporosis is the predominant feature here. The findings of lacunar resorption, however, together with the serrated periosteal surface of the cortex and the definite osteoid borders of the trabeculae of the spongiosa, are evidence that something more than senile atrophy is present. The periosteal surfaces of the bones in the cases of severe senile atrophy reported by Pommer and by Gerth are smooth. Furthermore, in the present case, small areas of fibrosis were found not only in the collapsed vertebral bodies, but also in others, as well as in areas of the ribs and in the femoral diaphysis. Without entering into a discussion of the various theories as to the mechanism of decalcification in renal osteodystrophy, the features of this case suggest that, in a senile individual in whom there is atrophy of most of the tissues, the addition of another factor favoring decalcification must be reflected in the bones to a much greater extent than would be the case in a person whose skeleton was more normally calcified.

Parathyroids

In nearly all cases of renal osteitis fibrosa previously reported, hyperplasia of the parathyroids has been a prominent feature. It would seem to be established from numerous clinical and experimental studies[13,28] that chronic renal insufficiency initiates a secondary or compensatory hyperplasia of the parathyroids, the exact mechanism of which still is subject to speculation. The subject has been well covered in a number of comparatively recent articles[1,3,18,31,32,33]; it would be superfluous to add further speculation on the basis of this case alone. Both chronic acidosis and hyperphosphataemia were present, without evidence of parathyroid hyperplasia. Perhaps the duration of severe renal insufficiency was too short for the hyperplasia to become evident. It might be argued that the larger gland in this case represented, in consideration of the atrophy of the other organs, a mild degree of hyperplasia. With this in mind, it was serially sectioned, but could not be made to conform to published criteria for parathyroid hyperplasia[13,28]. In Kurokawa's study of 815 parathyroid glands from 240 necropsy cases, numerous glands of approximately this size are reported as being found in widely differing conditions, and considered to be within the range of normal variation. In view of the undoubted atrophy of one of the glands in this case, and the hyalinization of the stroma of another, it is interesting that neither Kurokawa nor Castleman and Mallory found evidence of atrophy of the parathyroid glands in patients of advanced age.

A few cases of renal failure associated with skeletal changes have been reported, in which there was no parathyroid hyperplasia. Platt reported briefly a case of renal dwarfism in an eighteen-year-old boy in whom "there was no enlargement of the parathyroids". Bergstrand mentioned the case of a nephritic seventeen-year-old youth with lacunar resorption and early osteitis fibrosa, in whom there was no parathyroid enlargement. In Brown and Ginsburg's case, parathyroid tissue was not found. In all other case reports in

genographic examination "because of apparent shortness of the left lower extremity". Roentgenographic study showed multiple small bony bodies, scattered about the region o all the joints examined. Geyman felt that these findings were indicative of a form o chondrodystrophy. The roentgenographic findings differed from ours in that many of th epiphyses appeared ragged. In our cases, the opacities were within the cartilage and no scattered about the region of the joint.

Lightwood, in the same year, reported stippled epiphyses in an eleven-month-old child. This child had double congenital cataract, a finding seen in other reported cases The patient died of acute miliary tuberculosis, a few days after admission.

Bateman, in 1936, reported two cases of what he termed "punctate epiphyseal dysplasia". His first patient had congenital cataracts.

Bloxsom and Johnston, in 1938, reported a case of "calcinosis universalis". Their patient had skin involvement at birth, consisting of various sizes of creamy-colored horny plaques. The patient's left leg was short, and was held in a flexed position. Roentgenograms showed multiple calcified areas throughout the cartilaginous portions of the long bones, and in the regions of the carpi and tarsi. Because the child was making a spontaneous recovery, and because of high blood calcium three days after birth, Bloxsom and Johnston concluded that there had been a disturbance in the calcium metabolism of the mother or in the placenta, which caused abnormal deposition of calcium in the infant's body.

In 1939, Maitland described two cases, both of which had double congenital cataracts. The father of the children had a congenital absence, or presence in rudimentary form only, of the phalanges of the hands and feet. Maitland's conclusions were: "The condition ·ould seem, therefore, to be a direct hereditary transmission through the line of the male arent to the younger daughters".

Raap, in 1943, was the first to give a comprehensive summary of previous cases. He resented an investigation of four cases, with a report of a postmortem examination in one ıstance. His microscopic examination showed "an increase of fibrous tissue of periosteal haracter. Directly under this periosteum a formation of cartilage is noted. The deeper ells are acquiring a cartilaginous character. The deepest layers of cells form osteoid tissue, which is partly calcified. There is no evidence of malignancy." He called the condition "chondrodystrophia calcificans congenita". He had followed his cases for a period of four years and came to the conclusion that, although these abnormal calcifications were marked at birth, they disappeared by the age of three.

In May 1944, Borovsky and Arendt reported a similar case and called it by the same title as Raap. The child had flexion deformities of the knees, where the calcium deposit was the heaviest. They found that the deposits of calcium could not be considered stippled epiphyses, because the epiphyses were well developed. Their conclusions were that the condition could best be placed in the category of chondrodystrophia, that no special treatment seemed necessary, and that the prognosis was good.

The two cases reported here occurred in members of the same family.

Case 1. On October 19, 1944, a two-month-old white girl was admitted to the Cincinnati Children's Hospital for correction of bilateral congenital calcaneovalgus deformity. Routine roentgenographic studies of the long bones, wrists, elbows, ankles, knees, and spine, made on October 27, 1944, before correction, showed the epiphyses to have a stippled appearance, as though broken up into innumerable small fragments. The arrangement of these calcareous opacities was very irregular, and followed no definite pattern; they lay within the cartilage. They were found in most of the joints, but were most numerous in the region of the tarsi. There was also stippling at the ends of the femora and at the proximal end of each humerus. In the bones or periosteum none of the signs of congenital syphilis were seen, nor any constitutional abnormalities (Figs. 1-A and 1-B).

History

The child was born at the end of eight months of pregnancy and forty-eight hours of labor. Cephalic forceps were used. The weight at birth was five pounds and nine ounces. No cyanosis was present.

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RENAL RICKETS

Report of a Case

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The literature still contains fewer than one hundred reported cases of the syndrome of renal rickets. This is probably an apparent rather than a real rarity, however, as many cases undoubtedly terminate without the true etiology being appreciated or without the recognition of the association between the skeletal deformity and the renal abnormality. Such was the situation in the early history of the case to be described.

genographic examination "because of apparent shortness of the left lower extremity". Roentgenographic study showed multiple small bony bodies, scattered about the region of all the joints examined. Geyman felt that these findings were indicative of a form of chondrodystrophy. The roentgenographic findings differed from ours in that many of the epiphyses appeared ragged. In our cases, the opacities were within the cartilage and not scattered about the region of the joint.

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History

The child was born at the end of eight months of pregnancy and forty-eight hours of labor. Cephalic forceps were used. The weight at birth was five pounds and nine ounces. No cyanosis was present.

The family history was non-contributory; but the father had suffered a well-developed psychoneurosis.

The patient had been the product of a nine-month gestation and weighed six pounds and twelve ounces at birth. She experienced an illness of unknown cause during the neonatal period, which left her weighing only four pounds at the time of hospital discharge; but good health was soon regained and continued until the age of two years, when she had pyelitis which continued to give trouble until the age of five. During childhood she experienced measles, mumps, chickenpox, and whooping cough, but all without apparent complication.

A review of systems disclosed only that the child's appetite had been poor and that dyspnoea occurred with mild physical exertion; nocturia was occasional, and the menses had not yet occurred.

Physical Examination

The temperature was 98.6 degrees, pulse rate 110 and respirations 25 per minute, body weight fifty-seven pounds (the average for a fourteen-year-old female is 114 pounds), and height fifty-four inches (expected height sixty-two inches). The patient was a small, thin, weak girl of blonde complexion, who appeared chronically ill and exhibited a marked bilateral genu valgum deformity. She appeared reluctant to walk, and when she did so it was with a waddling type of gait. The scalp was normal. External ocular movements were normal; the pupils reacted to light and accommodation; eyegrounds were normal. The ears and nose were normal. The teeth were in fair condition. Small anterior and posterior cervical lymph nodes were palpable. Chest inspection and palpation revealed the presence of a rachitic rosary. The lungs were normal to inspection, palpation, percussion, and auscultation, as was the heart. Abdominal examination disclosed the presence of small inguinal nodes; the liver was palpable two fingers' breadth below the costal margin. Pubic hair was absent; the breasts were very small. Reflexes were all present and active. The extremities showed bilateral genu valgum and pes planus. There was no limitation of motion of the joints and no reduplication of the epiphyses, as seen in untreated cases of infantile rickets.

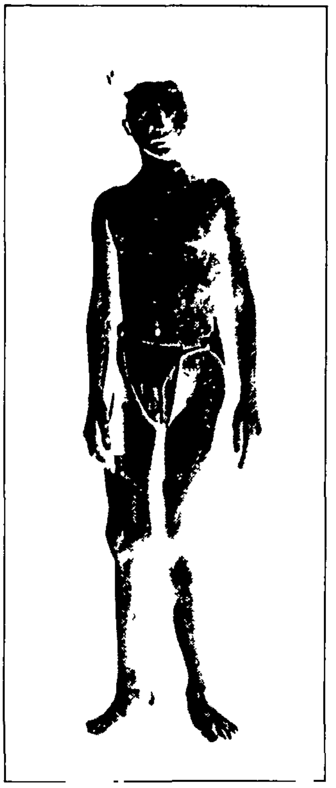

FIG. 1

Appearance of the patient shortly after admission to the Hospital. Height fifty-four inches, weight fifty-seven pounds. Delayed development of secondary sex characteristics is apparent. The degree of knock-knee is equal bilaterally, but the postural external rotation of the right leg partially obscures the deformity on that side.

Laboratory Examination

The red blood cells numbered 3,450,000; hemoglobin 65 per cent. Urinalysis showed a specific gravity of 1.010 and a trace of albumin; an occasional epithelial cell per high-power field was present. The serum calcium was 9 milligrams and the phosphorus 4.8 milligrams per 100 cubic centimeters of blood; the serum phosphatase was 17.8 milligrams per 100 cubic centimeters of blood (Kay units).

Hospital Course

Roentgenograms of the knees and hips showed a loss of definition at the epiphyseal plates with irregularity of structure and contour. At the hips there was partial displacement of the femoral neck in relation to the epiphyseal body, and coxa vara deformity bilaterally. On several attempts, there was inability of the kidneys to concentrate above 1.014; the phenolsulfonephthalein test showed less than a measurable amount of dye excreted in one hour. Retrograde pyelography demonstrated a normal urethra and bladder; good instrumentation of the left ureter was possible, and a satisfactory filling of the left renal pelvis, which appeared normal to subsequent roentgenographic examination. On three separate attempts at catheterization of the right ureter, however, the catheter stopped at eight centimeters; the dye injected returned down the ureter and produced pain with less than one cubic centimeter. Roentgenographic visualization of the right renal pelvis was not effected. Intravenous urograms were then obtained, films being made at intervals of 10, 20, 30, 60, and 120 minutes after injections of iodine compound. No opaque shadows appeared on any of the films, thus indicating poor kidney function. Meanwhile, the blood chemistry was as follows: non-protein nitrogen 128.6 milligrams, uric acid 4.9 milligrams, and creatinine 5.0 milligrams per 100 cubic centimeters of blood. The serum albumin was 6.2 grams and the serum globulin 1.2 grams per 100 cubic centimeters of plasma. The urea nitrogen was 107.5 milligrams per 100 cubic centimeters of blood.

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OSTEOCHONDRITIS OF THE SUPRATROCHLEAR SEPTUM

Report of a Case

BY W. T. ROSS, F.R.C.S., JOHANNESBURG, SOUTH AFRICA

In January 1945, Morton and Crysler[1] reported a series of six cases of osteochondritis dissecans of the supratrochlear septum, which condition they stated had not previously been described in the literature. Another case is reported here.

The patient, aged twenty-one, was an airman in the Royal Air Force. At the end of 1944, he knocked his right elbow while doing dinghy drill. For some weeks he complained of stiffness in the elbow. This improved, but the elbow never quite returned to normal, and he found it difficult to extend it fully.

Fig. 1

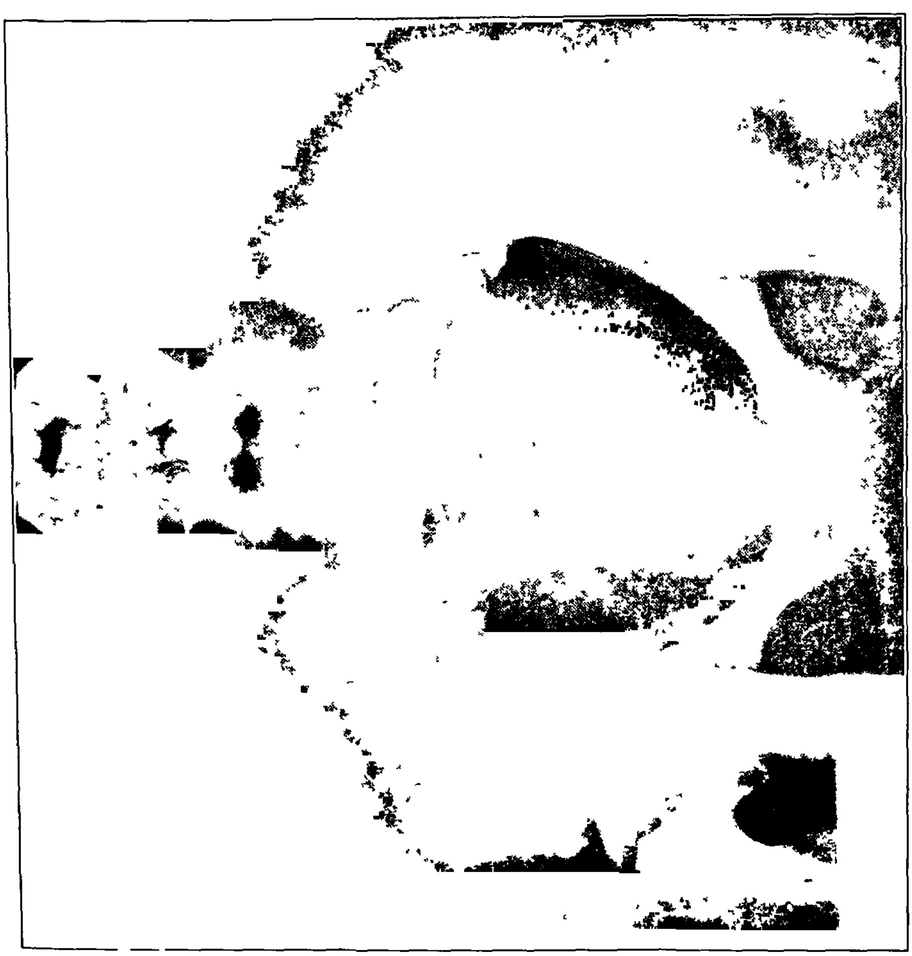

Fig 3

Fig. 4

Fig. 3: A view of both hips demonstrates the markedly developed rachitic process and the resulting epiphyseolysis.
Fig. 4: Attempted retrograde pyelography resulted consistently in an arrest of the catheter on the right side. The pelvis of the left kidney is shown to be relatively normal, but intravenous pyelography demonstrated that advanced parenchymal damage was present.

He was examined on December 31, 1945. The elbow appeared normal in all respects, exce extension was limited by 25 degrees. Attempts to force full extension caused pain behind th Roentgenograms (Fig. 1) showed an oval, calcified, loose body, lying in the olecranon fossa. T itself appeared larger than normal, with some sclerosis of its walls. As the elbow was extended, t body clearly tilted when the olecranon process came into contact with it (Fig. 2).

On February 6, 1946, a posterior incision was made just lateral to the triceps tendon. The tric incised longitudinally, and the joint was opened. Lying in the olecranon fossa was a completely smooth, oval body, which was easily removed. The supratrochlear septum was very thin and sp pressure, with two or three small apertures in it. The wound was closed in layers, and a firm was applied.

By March 4, 1946, the wound was well healed and the patient had regained full movements elbow. Postoperative roentgenograms of both elbows (Fig. 3) showed the fossa clearly defined right humerus, from which the loose body had been removed.

DISCUSSION

This case appears to be identical in all respects to those described by Morton Crysler. However, it is possible that the loose body did not arise from the supratroc septum by a process of osteochondritis, as they suggest, but rather from some other of the joint—such as the capitellum—and that it became wedged in the olecranon f As the olecranon process must impinge upon such a body, lying in this fossa, many dreds of times a day, it seems reasonable to postulate that the loose body thus deep its own bed on the posterior aspect of the supratrochlear septum, and did not act arise from the septum itself. Unfortunately, the loose body was not examined h logically.

NOTE: The author wishes to thank Air Commodore H. Osmond Clarke, C.B.E., for kind permi to publish this case.

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CHONDRODYSTROPHIA CALCIFICANS CONGENITA

Report of Two Cases

BY THEODORE H. VINKE, M.D., AND F. PAUL DUFFY, M.D., CINCINNATI, OHIO

From the Orthopaedic Department of the College of Medicine, University of Cincinnati, and the Orthopaedic Service of the Cincinnati Children's Hospital

Chondrodystrophia calcificans congenita was first described in 1914, by Conradi, who considered this condition an abortive form of chondrodystrophy, or achondroplasia. Many other authors have used the term stippled epiphyses[1,8,10,12,14], and considerable confusion exists in the literature concerning this condition. The present report represents cases of multiple calcareous opacities, lying within the cartilage of the epiphysis. Another entity, described by Borovsky and Arendt, differs roentgenographically from the cases reported here in that the epiphyses did not appear stippled. A stippled appearance was present in our cases during infancy, and it gradually disappeared without treatment. The two patients were members of the same family; a familial tendency is also suggested by Raap's cases.

The condition can be diagnosed only by roentgenographic examination. It produces no pain or local manifestations, although in several cases congenital cataracts have been observed[1,2,7,9], as well as other congenital malformations. Laboratory studies, including blood chemistry, show no abnormal findings. Hypothyroidism has been associated with epiphyseal dysgenesis, but its relation to chondrodystrophia calcificans congenita is questionable.

Pathologically, calcareous deposits in degenerative connective tissue have been found by Tisdall and Erb. A review of the American and British literature reveals nine similar case reports.

The first report in America of a case of calcareous deposits in the joints was made in 1924 by Tisdall and Erb. It is probably just coincidence that the patient's feet were everted, similar to our patients' feet. In addition to this abnormality, their patient had flexion deformities, involving almost all the joints of the body. Such deformities were not present in our cases. Unfortunately, no roentgenograms were taken of the trunk, hips, or hands in Tisdall and Erb's case. Roentgenograms of the wrists, elbows, shoulders, knees, and ankles in their case were reported as follows: "Peculiar irregular (calcareous?) deposits are present in the epiphyses at both ends of the humeri, the proximal ends of the radii, ulnae and tibiae and the distal ends of the femora. The patellae are practically outlined by these deposits."

Laboratory studies suggested no explanation for these findings. The child, who was five weeks old when first observed, died during the period of observation. A patent ductus arteriosus was found at postmortem examination. Microscopic examination of the patella

Fairbank, in 1927, reported two cases. The first patient, seen at one month of age, had congenital shortness of one leg. On roentgenographic examination it was found that: "The epiphyses of the long bones of the leg, and the tarsal bones, are represented by a number of discrete dense spots giving a curious stippled appearance". This patient died
number of discrete dense spots giving a curious stippled appearance". This patient died
when nine months of age. His second patient was two years of age when seen. The roentgenographic findings were similar. Fairbank's conclusions were that it was difficult to fit these findings into the dyschondroplasia group, and that it was necessary to regard them as examples of a new affection.

Geyman, in 1931, reported a case of a two-month-old child, brought to him for roent-

FIG. 1-B

An earlier roentgenogram made on September 28, 1942, and obtained from the patient's local physician, showing the onset of the lytic process in the left ilium.

nineteen inches (about 48.3 centimeters) from the anterior superior spine of the ilium to the medial malleolus; the right leg measured twenty and one-half inches (about 52 centimeters) between the same reference points. The apparent length of the left leg, as measured from the umbilicus to the medial malleolus, was twenty-two and one-half inches (about 57 centimeters); the apparent length of the right leg, between these reference points, was twenty-three and one-half inches (about 60 centimeters). Trendelenburg test for stability of the hip was positive on the left.

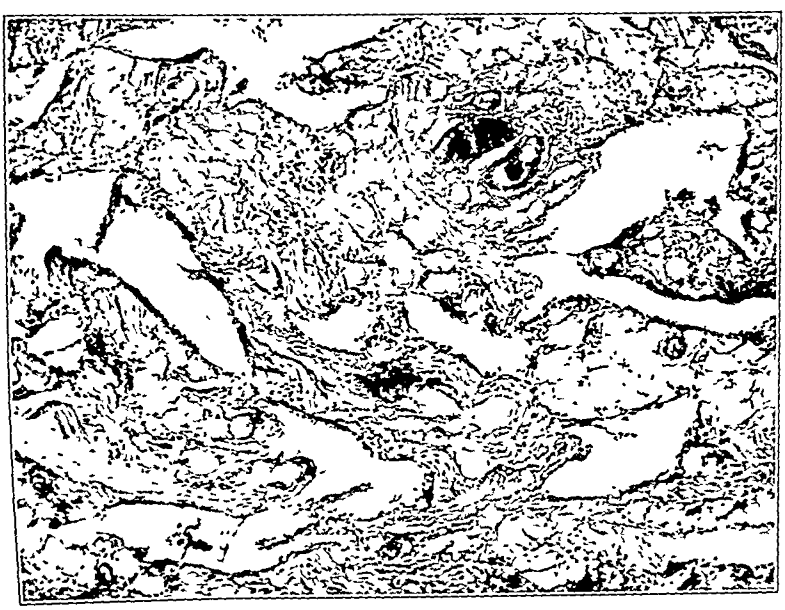

FIG. 2

Photomicrograph (× 50) showing fat and fibrous tissue that have been infiltrated by lymphangioma (hematoxylin and eosin stain).

Weakly positive reactions were obtained routinely to the Kline, Kahn, Hinton, and Wassermann tests. These results were thought to be caused by the recent episode of chickenpox from which the child was recovering. The presence of syphilis could not be established. Results of urinalysis were negative. The value for hemoglobin was 12.9 grams per 100 cubic centimeters of blood. Erythrocytes numbered 4,000,000, and leukocytes, 14,600 per cubic millimeter of blood. The differential count was within essentially normal limits. Using the Westergren method, the sedimentation rate was 9 millimeters in one hour. Studies of blood chemistry revealed the value for calcium to be 10.9 milligrams, and that for phosphorus, 5.2 milligrams per 100 cubic centimeters

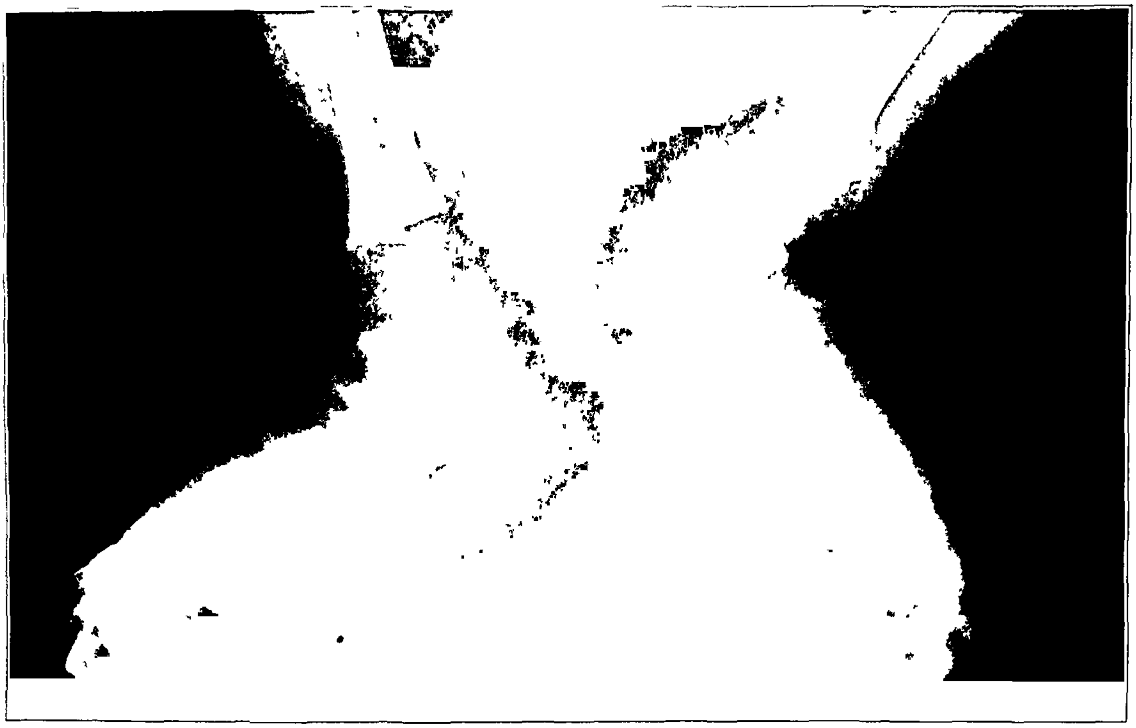

Fig. 1-A

Case 1. Roentgenogram of infant's feet, showing numerous calcareous-appearing deposits of irregular shape in the region of the tarsi.

She had been breast fed since birth. No cod-liver oil or orange juice had been given.

The father and mother were each twenty-one years of age and in good health. Neither parent had a family history of abnormalities. There had been one previous pregnancy, but no abortions or still-births. The other child was living and well, but a similar deformity of his feet had been present at birth.

Physical Examination

On admission the child weighed six pounds and ten ounces. She was a white girl, two months old. The general appearance was that of a well-developed and well-nourished infant, who appeared about the stated age. No lymphadenopathy was observed. The skin was of normal color, moisture, and texture. No petechiae or lesions were noted. The head was normal in size and shape. The eyes showed no evidence of cataract or other abnormality. A tendency toward saddle-nose deformity was observed. The ears and throat showed no abnormal findings. The thorax was normal in shape and contour. The chest was clear to percussion and auscultation. The heart was not enlarged; the rhythm was regular; and the rate was 110 per minute. No murmurs were heard. The genitalia were normal. The extremities were symmetrical and showed no inequalities in length. The feet were everted; they were flat and broad across the tarsi, with marked abduction and pronation of the fore part of the foot. They were held in a calcaneovalgus position. There was no limitation of motion of the other joints. The reflexes were physiological.

Fig. 1-B

Roentgenogram of wrist, showing calcareous-appearing deposits in region of carpal bones and in first metacarpophalangeal joint.

FIG. 4

Roentgenogram made on August 8, 1945, showing extension of destruction to the sacrum and the fourth and fifth lumbar vertebrae.

of serum. The value for phosphatase was 6.6 units per 100 cubic centimeters of serum, as determined by the Bodansky method. Reaction to the tuberculin test in the first strength was negative. Roentgenograms of the pelvis, which were made at the Clinic, showed almost complete absence of the left ilium from the sacro-iliac joint to the acetabular region, there being a small remaining portion of the roof of the acetabulum over the middle half of the head of the femur (Fig. 1-A). The left side of the pelvis was "telescoping" into the pelvic viscera. There was no evidence of any formation of new bone in this area. Roentgenogram of the skull did not disclose disease of the bone.

In the absence of any tumefaction and symptoms, the first consideration was that of congenital absence of the ilium. The child's mother, however, on reviewing the roentgenograms, felt that they did not show the same picture as the original ones that had been made elsewhere. Consequently, the latter roentgenograms, made on September 28, 1942, were obtained and reviewed. They showed that an osteolytic process involved the posterior portion of the ilium, and extended down toward the acetabulum (Fig. 1-B). Dissolution of the sacro-iliac joint had already begun. Hence, the problem of differential diagnosis and treatment became most difficult. Biopsy was proposed and carried out on December 21, 1943.

An elliptic incision was made over the anterior superior spine of the ilium and over what would normally be the crest of the ilium. The muscles were dissected down to what remained of the acetabulum. After the incision had been made, and, as the aforementioned procedure was being carried out, a thin, straw-colored fluid exuded, similar to the fluid seen in the presence of lymphoedema. Pressure on the tissues caused oozing. Some of the tissue, cartilage, and bone from the region of the acetabulum was removed for histopathological examination. After the bleeding had been stopped, the incision was closed in the usual manner. Long-leg traction in moleskin was applied, postoperatively.

Macroscopically, the tissue removed was without significance, because it consisted of small pieces of cartilage, bone, and adjacent soft tissue in which the normal anatomical relationships had been lost. Histopathologically, the small pieces of cartilage and bone were unsatisfactory for study, because they did not reveal the true nature of the lesion. On the contrary, however, histopathological study of specimens of the adjacent soft tissue disclosed that a lymphangioma had infiltrated the fat, fibrous tissue, and muscles. The lymphangioma consisted of lymphatics and lymph sinuses lined with flat endothelium (Fig. 2).

Because of the collapse of the pelvis, it was thought wise to attempt to restore it by any method

CASE 2. This boy, two years and eleven months of age, was a brother of the child presented as Case 1. His feet had been mildly everted at birth, but not so much as his sister's. Roentgenographic examination of the long bones, ankles, knees, hips, wrists, elbows, and spine revealed abnormal findings only in the films of the ankles and feet. Scattered throughout the region of the tarsi, irregular calcareous-appearing deposits were seen within the cartilage. These were similar to those seen in the films of the patient's sister, but were not so numerous (Figs. 2-A and 2-B).

History

The child had been born after a full-term pregnancy, with forceps delivery. No cyanosis had been present. The only deformity was slight eversion of the feet.

He had been fed breast milk and bottled milk until eight months of age. Cod-liver oil and orange juice were started at three months of age; vegetables were started at four months, and meat at six months.

Physical Examination

The patient was a well-developed and well-nourished child, three years of age. The only abnormal finding was mild pronation of the feet, with medial prominence of the tarsi.

Blood Wassermann tests of the mother and child were negative. Roentgenographic examination of the mother showed no abnormal findings. Roentgenographic examination of the father was not possible, since he was in Europe at the time.

SUMMARY

Case reports of a two-month-old white girl and of her brother, aged two years and eleven months, are presented because of the roentgenographic findings of calcareous deposits within the cartilage of the joints and in many epiphyses. The girl was admitted for orthopaedic correction of talipes calcaneovalgus deformity, and the calcareous deposits were discovered during routine roentgenography. All laboratory studies failed to disclose the cause for the deposits. The boy had scattered irregular calcareous deposits within the cartilage about the tarsal bones, but these were less numerous than those found in his sister.

After study of the British and American literature, nine similar case reports of infants were found. Several patients had congenital heart lesions or cataracts. Neither of these conditions was found in our patients. Several of the case reports mention stippled epiphyses in older children[4,10,12,13,14]. These cases are not similar to ours, because the authors report stippling of the epiphyses without the presence of diffuse calcareous opacities within the cartilage. We contend that our cases represent an entity separate and distinct from that occurring in older children.

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Clinically, although the patient was still without pain, she was being taken to and from school, and was using a wheel chair. She was unable to walk without a marked limp.

COMMENT

Histologically, the periosteum of normal bone contains a rich plexus of lymphatic capillaries. It is possible that this tumor arose in the periosteum, and gradually caused dissolution of the ilium, ischium, and portions of the vertebrae, by invasion of the blood and lymph spaces contained therein. Not much is known about the lymphatic vessels of the bone marrow and cancellous bone, but such porous structures, rich in body fluids, must certainly contain lymphatic vessels. It is known that lymphatic vessels do accompany the blood vessels in the Haversian canals. Hence, it is conceivable that this tumor could arise primarily within the bone.

The question as to whether this tumor could have arisen in the soft tissue surrounding the bone, and caused secondary erosion of the ilium, is a speculative one. However, since there is ample room for expansion of such a lesion into the surrounding tissue, it is difficult to conceive that the ilium should have disappeared because of pressure erosion in the absence of tumefaction. Explanation of the progressive extension across joint lines is difficult, unless it is accepted that the origin of the tumor was periosteal. In the literature several cases have been reported in which rather acute spontaneous absorption of bone had occurred. The tissue in these cases, however, exhibited degeneration, and was not inflammatory or neoplastic.

RUPTURE OF THE POPLITEAL FASCIA

BY HOWARD R. DUDGEON, JR., M.D., WACO, TEXAS

Although a great deal has been written about knee injuries, especially cartilage injuries and fractures into and around the knee joint, rupture of the popliteal fascia with herniation of the hamstring muscles has not been discussed adequately in the medical literature. The condition is not rare, but is uncommon. In the standard texts of anatomy are described two layers of fascia in the popliteal region,—the superficial and the deep, or popliteal, fascia. The popliteal fascia is thin, but possesses considerable strength because of the transverse fibers which are interwoven among its longitudinal fibers[2]. It is firmly attached on each side to the tendons of the muscles which bound the popliteal fossa. Proximally it is continuous with the fascia lata of the thigh.

Following are the reports of two cases,—one a recent injury to an Australian civilian, and the other an old injury to a soldier.

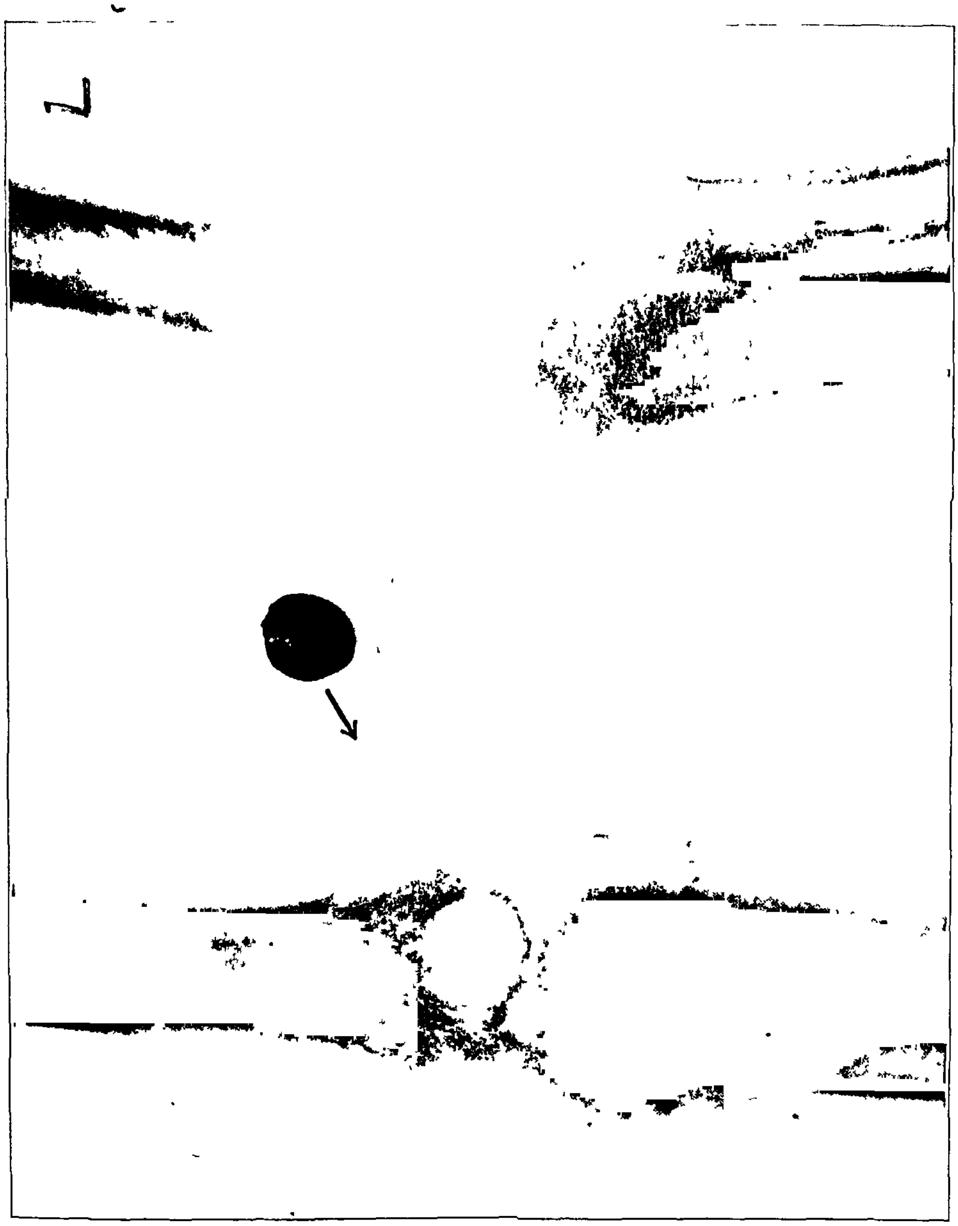

FIG. 3

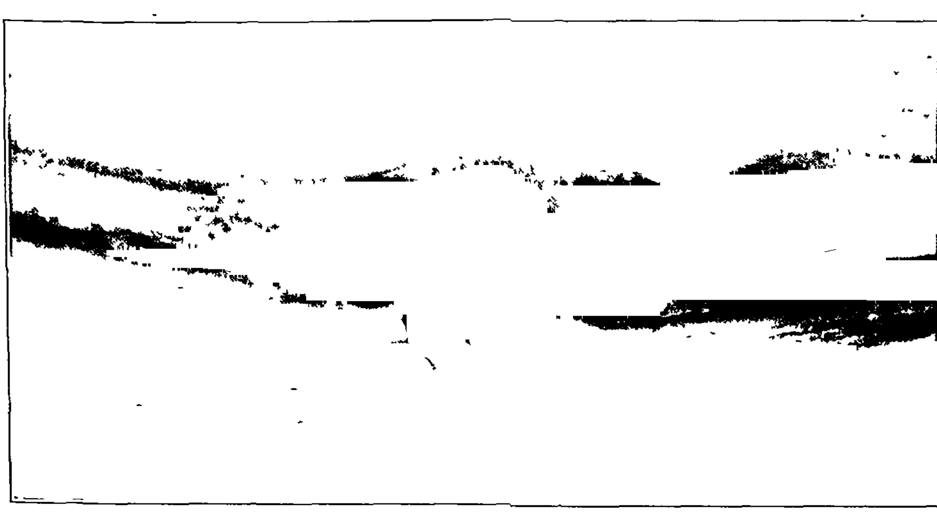

FIG. 2

A SLING FOR USE IN LEGG-PERTHES DISEASE

BY CLARENCE H. SNYDER, M.D., GRAND RAPIDS, MICHIGAN

It is generally agreed that good results can be obtained in Legg-Perthes disease, if treatment is begun early. This usually means some form of rest; frequently traction or a plaster cast is used, and sometimes a so-called non-weight-bearing caliper. Often the surgeon has difficulty both with the parents and with the patient, who usually is an otherwise healthy child and does not wish to be kept in a cast or in traction. The non-weight-bearing caliper does not give adequate rest or freedom from weight-bearing, and the results with this type of treatment have been poor. Some children have been treated by non-weight-bearing alone; crutches and sometimes a lift on the shoe of the good leg are used to keep them from putting weight on the involved side. Most of these patients will get better if they can be kept from weight-bearing. If kept in bed, however, they will sometimes get up on their knees, or walk around the room. When permitted to use crutches, they will disregard instructions at times and will walk or bear weight on the bad leg in spite of all observation and entreaties.

A sling, which the author has used in several cases in which the disease was unilateral, has proved most satisfactory.

F. H., an eight-year-old boy with unilateral Legg-Perthes disease. had an initial period of bed rest, after which he was allowed up with crutches; he continued, however, to bear weight on the involved leg, either walking or standing on it at times. His father asked

FIG. 1

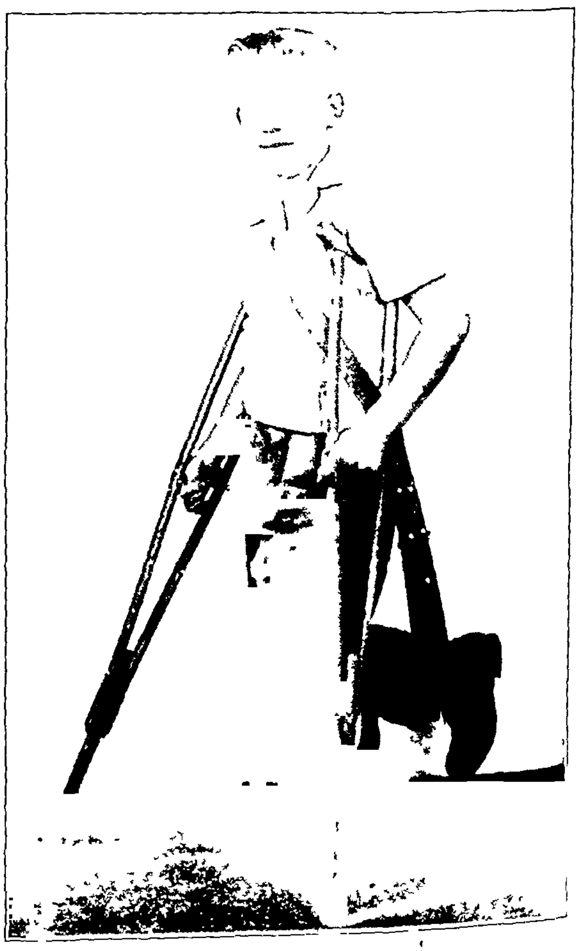

FIG. 2-A

Fig. 1: C. V., aged ten, is wearing the sling for Legg-Perthes disease which is made to hang posteriorly. This is better adapted for the use of a girl. In this case, the condition is still active.

Fig. 2-A: F. H. is shown wearing the sling for Legg-Perthes disease, hung from the side.

PRIMARY LYMPHANGIOMA OF THE ILIUM

Report of a Case

Y WILLIAM H. BICKEL, M.D., AND ALBERT C. BRODERS, M.D., ROCHESTER, MINNESOTA

From the Sections on Orthopaedic Surgery and Surgical Pathology, Mayo Clinic, Rochester

Lymphangioma of soft tissue is not an uncommon condition, as is evidenced by the y reports of such tumors in the literature. So far as can be determined, however, re are no recorded cases of primary lymphangioma of bone. Consequently, it was ught that the presentation of such a case would be of value.

CASE REPORT

A girl five years old was brought to the Mayo Clinic on December 1, 1943. A questionable diagnosis 'osteomyelitis of the left ilium" had previously been made. The child's mother stated that fifteen ths earlier, when the child had been three and a half years old, a limp had been noted in the left leg. nipulative treatment had been employed, and the leg had been stretched. In November 1943, a ntgenogram had been made, and a defect in the ilium had been noted. The child had never com- ned of pain, and had been able to keep up with her playmates in activities. However, the limp had ome progressively worse.

The history of this patient was essentially irrelevant to her condition. She had been born at full n, by spontaneous delivery; she had begun to walk at the age of one year, and her development, ept for the condition previously noted, had been normal. Shortly before the child was first seen, she had an episode of chickenpox, which had left some residual scales.

Results of a general physical examination were entirely negative. The patient's left leg measured

Fig. 1-A

Roentgenogram made on December 2, 1943, showing almost complete absence of the left ilium, with collapse of the pelvis on the left.

trochanteric region. It hangs either at the patient's side or behind him. The knee is flexed to about a right angle, and the weight of the sling is borne by the lower portion of the tibia. An additional small strap may be placed around the shoe, just anterior to the heel, to help hold it in place.

Most of the patients who have tried this sling have been boys, but some girls are now wearing it (Fig. 1). The children have been much happier, and more contented and co-operative since wearing the sling. They go where they wish, but avoid standing on the leg. They play games without worrying about weight-bearing, ride in cars, attend school, go swimming, get into the bath tub, *et cetera*. Night casts or traction have not been found necessary. The muscle spasm disappears after a few weeks; and quite normal rounding of the head of the femur results in due time without much muscle atrophy and, in most cases, with very little shortening of the limb.

A HANDY PIN INSERTER *

BY GEORGE R. DAWSON, JR., M.D., FLORENCE, SOUTH CAROLINA

A pin inserter, made from the "T" on a Jacobs chuck, is useful in various procedures. It is particularly advantageous when the left hand is needed to hold the part, as in transfixing an olecranon fracture or in transfixing a phalanx in arthrodesis of a toe.

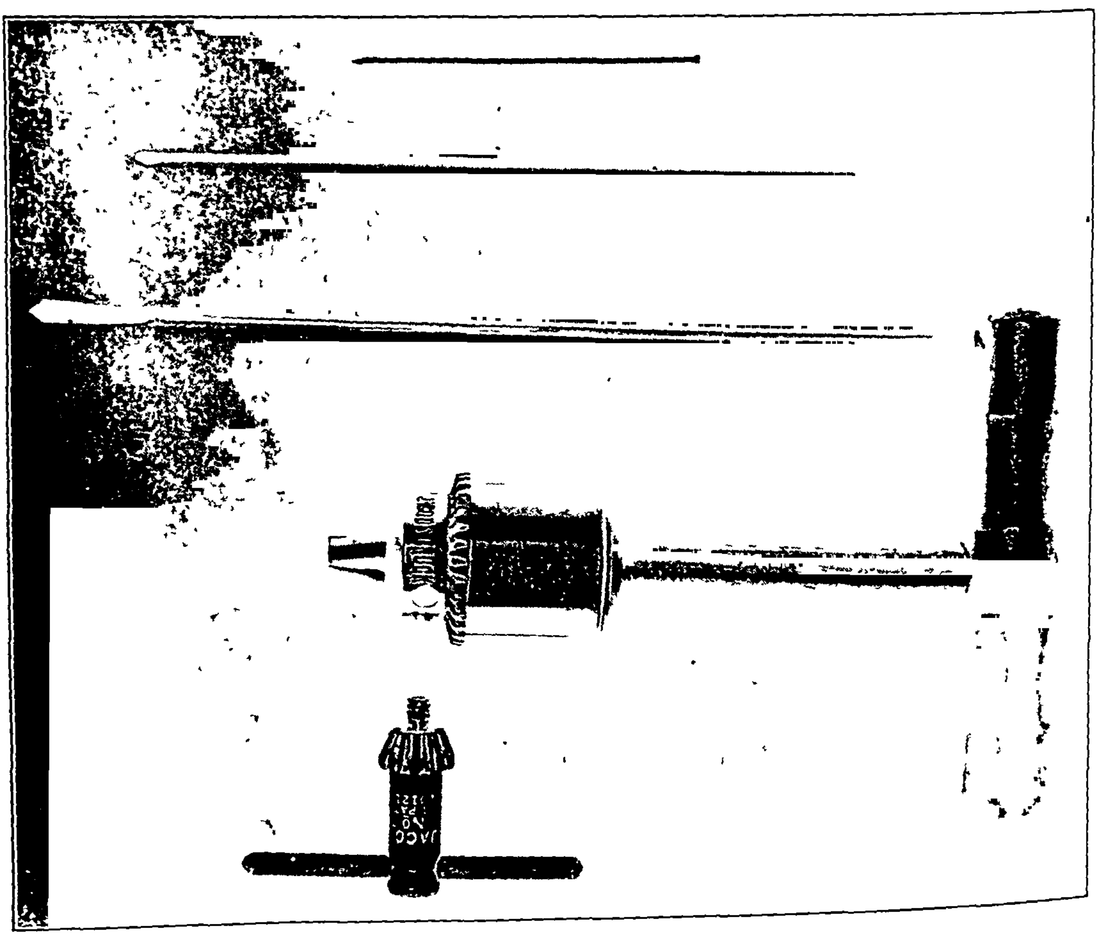

FIG. 1

* Exhibited at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1946.

FIG. 3-A

Roentgenogram made on February 18, 1944, showing pelvis after the patient had received the first course of roentgen-ray therapy and traction; the pelvic outlet has been restored somewhat.

FIG. 3-B

Roentgenogram made on July 20, 1944, showing beginning absorption of the ischium and continued absorption of the ilium.

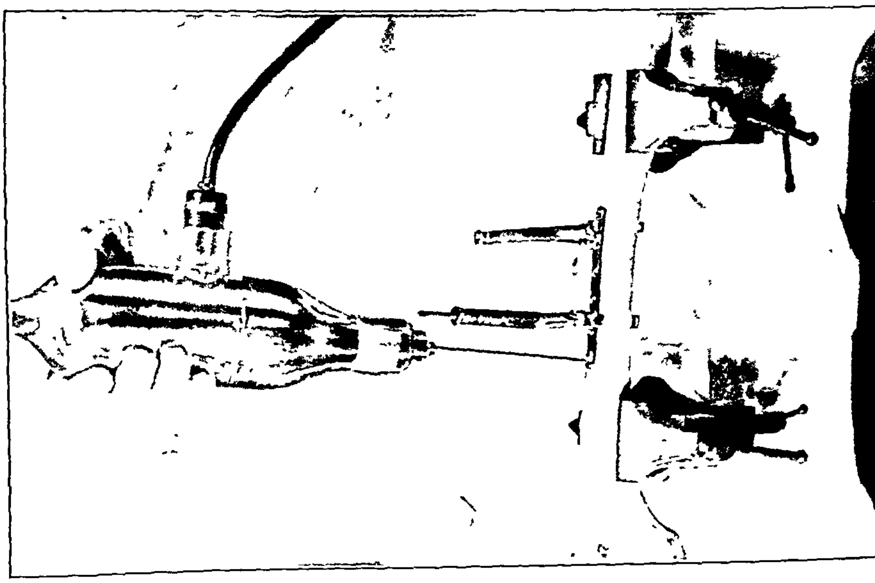

Fig. 4

The bone is held firmly in vises while holes are made with a motor-driven drill.

Fig. 5

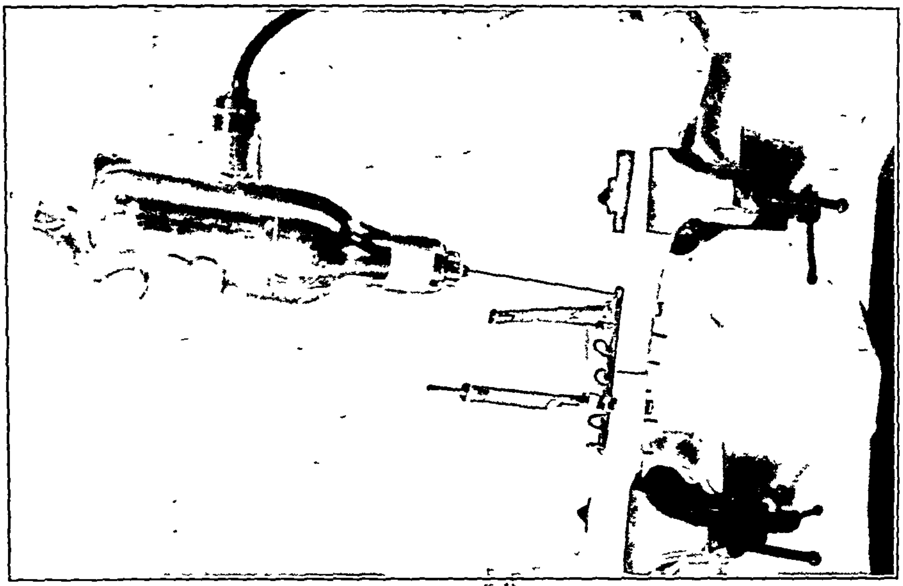

Fig. 6

After each hole has been drilled, a plug is inserted.

possible, while a course of roentgen-ray treatment was being administered. The patient was placed in a cast after the incision had healed, and a Hook-Martin traction apparatus was applied. This resulted in some degree of widening of the pelvic outlet, as evidenced by the roentgenogram made on February 18, 1944 (Fig. 3-A). After the patient's first series of roentgen-ray treatments, it was thought that some increase in formation of bone had occurred, and that no increase in destruction of bone had taken place.

The Kline, Kahn, Hinton, and Kolmer tests, made while the patient was in the Hospital, showed that the reactions had become negative.

Roentgen-ray therapy consisted of seven light doses, administered at monthly intervals. The last treatment was given on June 27, 1944. A roentgenogram made on July 20, 1944 (Fig. 3-B), showed some increase in destruction of that portion of the bone which remained above the acetabulum. An indented erosion situated just above the ischial tuberosity was noted. Further, some degree of collapse of the pelvis was noted; it was impossible to maintain the position that had been gained. It was felt that the patient had reached the limit of tolerance to roentgen-ray therapy, and that the tumor appeared to be not radiosensitive. Consequently, the therapy was discontinued.

The mother of the patient sent us a roentgenogram that had been made on August 8, 1945 (Fig. 4). In this roentgenogram marked extension of the lytic process was evident. The left ischium seemed to be disappearing, and it appeared that involvement of the sacrum and the fourth and fifth lumbar vertebrae had commenced, with nearly complete disappearance, on the left, of the facets between these vertebrae. Apparently, by this date, involvement of the head of the femur had not yet taken place. The patient's clinical course at that time was apparently the same. She had a painless limp.

Roentgenograms made on September 23, 1946, showed marked extension of the destructive process, so that more than two thirds of the left innominate bone had disappeared (Fig. 5). Dissolution of the pedicles of the vertebrae, facets, and spinous process on the left had occurred, with some degree of rotary displacement of the right sacro-iliac joint. There was some question as to involvement of the trochanteric region of the left femur.

Fig. 5

Roentgenogram made on September 23, 1946, showing pelvic deformity and extension of the erosion.

Holes are drilled in the bone, as shown in Figure 4. Into these holes are inserted plugs made from coat-hanger wire (Figs. 5 and 6). After each hole has been drilled, a plug is inserted to ensure the exact position of the plate. Figure 7 shows the screw holder inserted into the chuck, and Figure 8 shows the screw inserted into the screw holder.

The speed of driving the drill is determined by the pressure of the foot on the rheostat. The last few turns are made either by the motor-driven screw driver or by a hand screw driver. Figure 9 shows the screw holder being released.

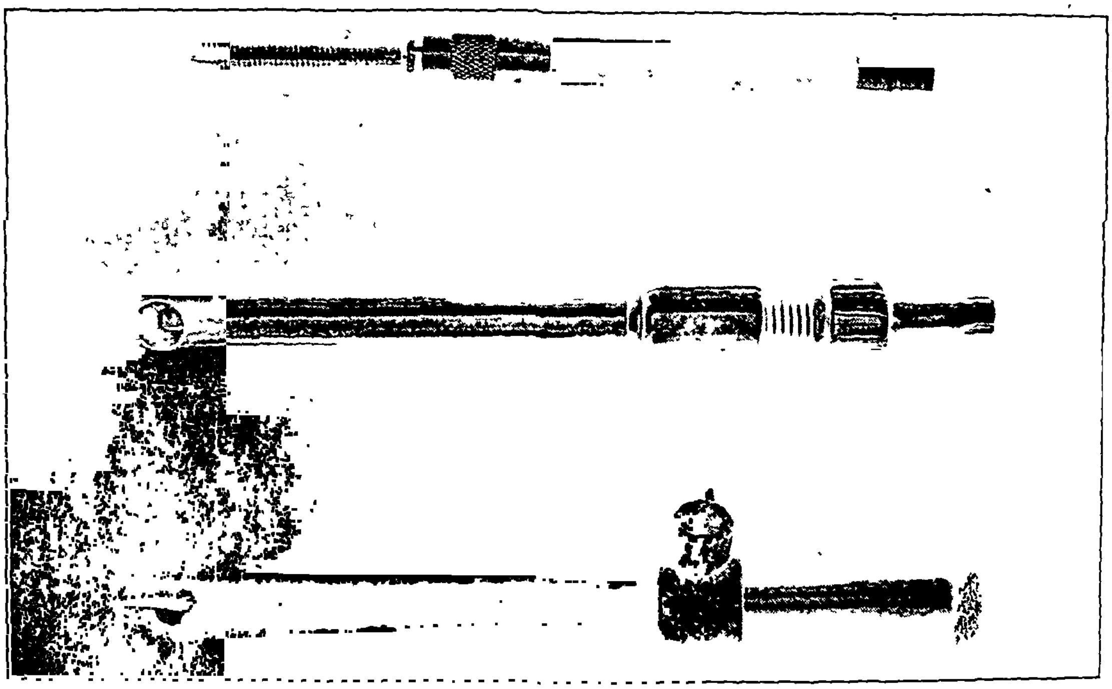

FIG. 10
Models A (at bottom), B, and C (at top). A screw has been inserted in Model C.

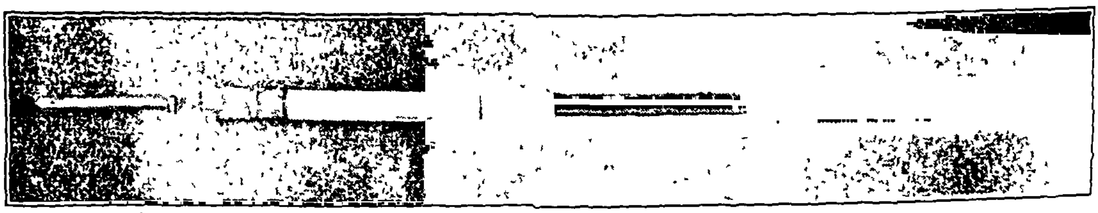

FIG. 11
Another view of Model C. Since there is no cuff to hold the screw, the screw can be driven all the way home in one movement.

Figure 10 shows the three models of the instrument. Model C is made by cutting off the handle of a five-sixteenths-inch "snap-on" screw driver and turning it in a lathe to fit the quarter-inch Jacobs chuck on the motor. The blade of this screw driver has in its middle third a tongue which rotates to hold the screw by friction. Model C has the advantage over Models A and B that it has no cuff to hold the screw, and therefore the screw can be driven all the way in with one movement; however, the screw is not held so firmly as it is in Models A and B, and the screw driver will jump off if the friction is too great.

CASE 1. J. K., an Australian civilian, aged forty-six, while lifting a heavy weight, had a sudden pain in the left popliteal space and had to sit down for about thirty minutes. When he attempted to walk, there was severe pain in the knee and rapid swelling in the popliteal space. When seen, three days later, the patient stated that he had been unable to work for the past three days and could walk without pain only when keeping his knee stiff. He felt that he had a "knot" on the back of his knee. There had been no previous knee injury.

The physical examination was negative, except for the left popliteal space. There was some discoloration of this area and, when the patient flexed his knee partially, a mass the size of a lemon appeared on the medial portion of the popliteal space. This mass was firm and tender on pressure. Full extension of the knee caused the mass to disappear; attempted extension of the partially flexed knee against opposition made it firmer and more prominent. No fluid could be aspirated from the mass, and roentgenograms were negative. There was no instability of the knee in any direction. The preoperative diagnosis was partial evulsion of the attachment of the semitendinosus or semimembranosus.

An operation was done, using 1 per cent. procaine and a mid-line incision in the popliteal space. The tissues were found to be infiltrated with blood and the popliteal fascia was torn obliquely. The muscle bellies and some of the tendinous parts of the semitendinosus and semimembranosus were found to herniate through the fascial rent when the knee was partially or completely flexed. The attachments of these muscles were not torn. The tear was overlapped and closed with interrupted sutures of No. 1 chromic catgut. The leg was immobilized in extension for two weeks with a thigh-length anterior splint. Gradual weight-bearing and exercise were started; complete recovery occurred in from five to six weeks.

CASE 2. A soldier, twenty-three years old, had a painful, unstable left knee and a mass in the popliteal space. Five years before, a tree had fallen on his knee, and he had been disabled for five or six weeks. Roentgenograms taken at that time showed no fractures. The mass was noticed after he had recovered from his injury and had resumed walking. It did not increase in size, but was more noticeable on flexion. The knee had been unstable since the accident. When seen, the patient was unfit for duty.

Physical examination disclosed a complete tear of the fibular collateral ligament. Roentgenograms were negative. There was a firm mass, the size of a walnut, in the popliteal space; this mass became more prominent on flexion of the knee and partially disappeared on extension. Locking of the knee did not occur.

Because a Baker's cyst was suspected, about 100 cubic centimeters of air was injected into the tumor. No fluid could be aspirated. Roentgenographically, no air was seen in the knee joint; most of it seemed to have traveled proximally in the muscle planes.

The patient was operated upon and a tear, one inch by two inches, was found in the popliteal fascia, with herniation of the muscle belly of the semitendinosus. After the fascia had been freed, the tear was easily overlapped with interrupted sutures of No. 1 chromic catgut. The ruptured fibular collateral ligament was repaired with fascia lata, according to the technique described by Campbell. The leg was immobilized.

The patient had an uneventful recovery and when last heard from, eight months after operation, was doing full military duty.

DIFFERENTIAL DIAGNOSIS

In these cases it is difficult to distinguish between a Baker's cyst[3], chronic bursitis around the knee joint, the usual fat pads in an obese person, and a lipoma. When there is doubt as to the diagnosis, aspiration should be carried out, if possible, and about 100 cubic centimeters of air injected. Roentgenograms should then be taken. If a Baker's cyst is present, there will be air in the knee joint; if a chronic bursitis, there will be air only in the bursa; if a fat pad, lipoma, or popliteal rupture is present, there will be air in the tissue and muscle planes. A history of injury and the fact that the mass is more prominent on flexion of the knee will aid further in making the diagnosis of rupture of the popliteal fascia.

If a ruptured popliteal fascia is causing pain and disability, surgical repair is necessary. The treatment of this condition is simple and satisfactory, if one realizes the abnormality which is present.

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normal. Obvious lateral bowing is corrected by applying more traction; by varying the amount of abduction; or, finally, by aluminum pressure pads, clamped to the splint. As soon as the position is satisfactory to external appearance and by measurement, roentgenograms are taken to check the position.

Static quadriceps exercises are begun immediately When the fracture has partially consolidated, a Pearson attachment is added to the Thomas splint, and knee motion is resumed. Weights and pulleys are attached so that a pull by the patient allows the knee to flex.* At this time, the amount of traction may be reduced to about eight pounds to facilitate flexion of the knee (Figs. 3-A, 3-B, and 3-C).

Traction is maintained for twelve weeks, or until the fracture is united clinically. The pin is then removed, and knee motion is continued while the extremity is maintained in suspension. When the roentgenograms show considerable callus, a Thomas caliper splint for ischial weight-bearing is applied and worn for at least six months to prevent refracture. During this time, the patient should exercise against resistance to regain full flexion of the knee and full power of the quadriceps.

DISCUSSION

The long stirrup permits treatment in the original Thomas or Jones manner, with the knee fully extended. Full extension of the knee is never lost, and quadriceps exercises may be begun earlier and more efficiently. In addition, most femoral fractures fall into position very easily with the knee in the extended position. Indeed, supracondylar fractures may be so treated, and, if treatment is started early, contracture of the gastrocnemius is not allowed to occur.

The author prefers the Steinmann pin to the Kirschner wire. The pin has very little

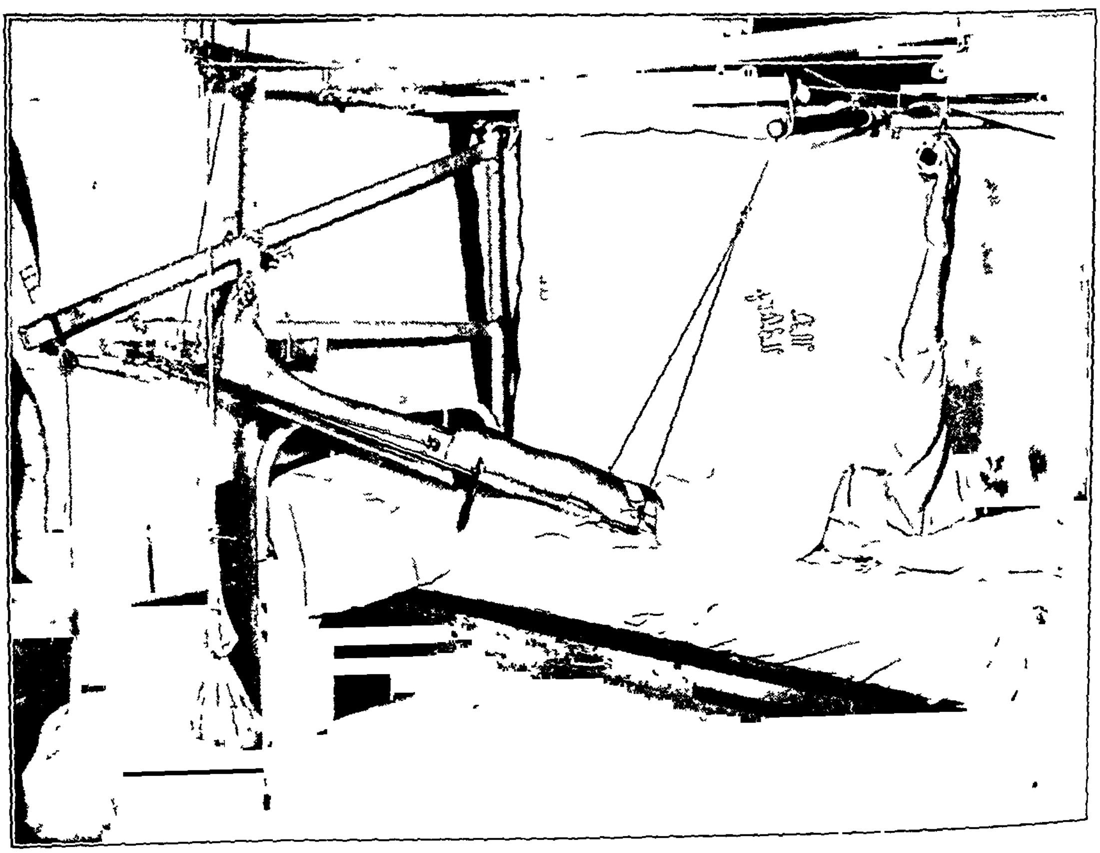

Fig. 3-A

Complete traction apparatus. The Pearson attachment is applied after the fracture has united sufficiently to permit knee motion. (*Photograph by U. S Army Signal Corps*)

* The discs of the stirrup should be oiled frequently to reduce rotation strain upon the Steinmann pin

for some sort of sling to help the child hold his leg off the ground, and the one shown in Figure 2-A was the result. Several children are now wearing this type of sling, and are able to walk with crutches and attend Orthopaedic School.

The sling may be made from leather or webbing, about one and one-half inches wide; it hangs from the opposite shoulder and is riveted together or sewed at the belt line or the

FIG. 2-B
Roentgenograms taken August 29, 1944, in the advanced stage of the disease.

FIG. 2-C
Roentgenograms taken August 26, 1946, show result two years later. The patient made a complete recovery, and had shortening of the leg of about one-quarter of an inch.

tendency to slip from side to side. It allows the use of the rotating stirrup, thus permitting knee motion without rotation of the pin in the bone.

The site of placement of the pin is still a subject of controversy. Many surgeons prefer the supracondylar position, believing that knee motion is easier with the pin in this position and that, in certain supracondylar fractures, an upward pull on the distal fragment may correct posterior angulation.

The supracondylar placement involves three distinct disadvantages:

1. The pin transfixes the tendons which move the joint. Motion of the knee is thereby limited by pain and pull on these tendons. In patients treated with apparatus requiring multiple pins, seldom is more than 25 degrees of knee motion present with the pins in place.

2. Experiences with femoral lengthening show that the pull of the femur inside its muscular cuff may jam the articular surfaces of the femur and the tibia, and may, if the knee is flexed, cause partial posterior subluxation of the tibia on the femur. This might occur in the treatment of older fractures with severe shortening.

3. The supracondylar pin is close to the synovial reflections, and may actually traverse them. This causes added secretion, which promotes the formation of adhesions in the suprapatellar pouch. A scar tract is formed between the femur and the tendons,—an additional factor to limit knee motion.

Conversely, insertion of the pin through the tibial tubercle is safe, since there is no danger of piercing the femoral artery or the suprapatellar pouch. Traction is placed upon the muscles causing the shortening, and the knee joint is not jammed. Knee motion may be started as early as the condition of the fracture allows, and does not cause pain. The author has never seen laxity of the ligaments of the knee when efficient quadriceps exercises have been carried out from the beginning of treatment.

DISCUSSION

(Continued from page 475)

disc injury. It is submitted that instability of the lower lumbar joints frequently is an underlying cause of disc rupture. In support of this is the fact that many of these patients give a history of back pain, preceding sciatica for months or years. Loss of the nucleus pulposus and subsequent flattening of the disc must have a detrimental effect upon the mechanics of the joint. It is believed that this accounts for the many cases in which back pain follows the removal of a herniated nucleus pulposus, although the sciatica is relieved. For these reasons it is our practice to do a spine fusion at the time of the disc operation in a majority of cases. By the use of internal fixation with screws, the period of confinement to bed and of subsequent disability is not prolonged over that following the simple disc operation.

In regard to the diagnosis of a herniated nucleus pulposus, chief reliance is placed upon the history of sciatic pain and the clinical examinations, made by both the orthopaedic surgeon and the neurologist. The patients are divided into two groups: (1) those in whom the neurological signs are characteristic and convincing, and (2) those in whom the nerve signs are less definite and not convincing. In the former group, a definite diagnosis of a herniated nucleus is made; in the latter, the condition is suspected and exploration is advised, especially if spine fusion has been decided upon.

At exploration, both the lumbosacral and the fourth and fifth lumbar interspaces should be examined, as we have found a small number of double herniations.

A MOTOR-DRIVEN SCREW HOLDER AND SCREW DRIVER *

BY GEORGE R DAWSON, JR., M D , FLORENCE, SOUTH CAROLINA

Several models of a motor-driven screw holder and screw driver are shown. Model A is shown assembled in Figure 1, and the parts are shown separately in Figure 2. Figure 3 shows the instrument inserted into a motor-driven chuck.

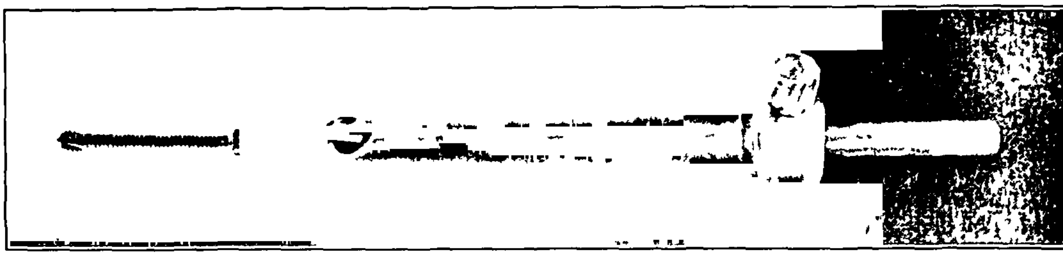

FIG. 1

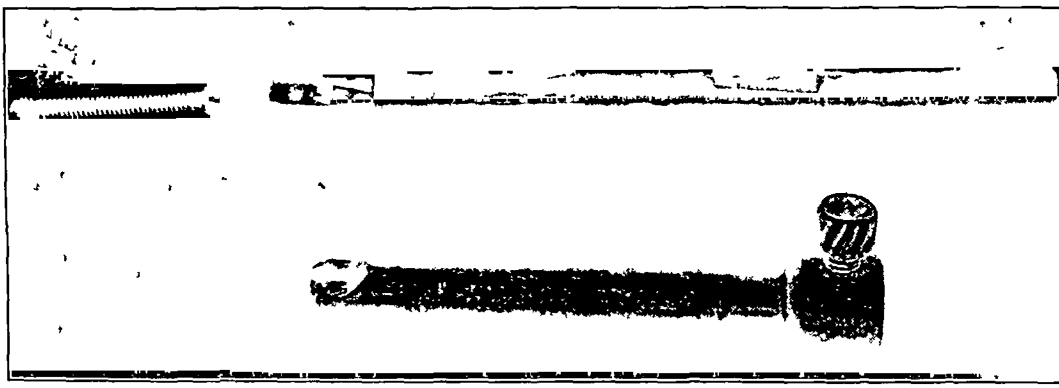

FIG 2

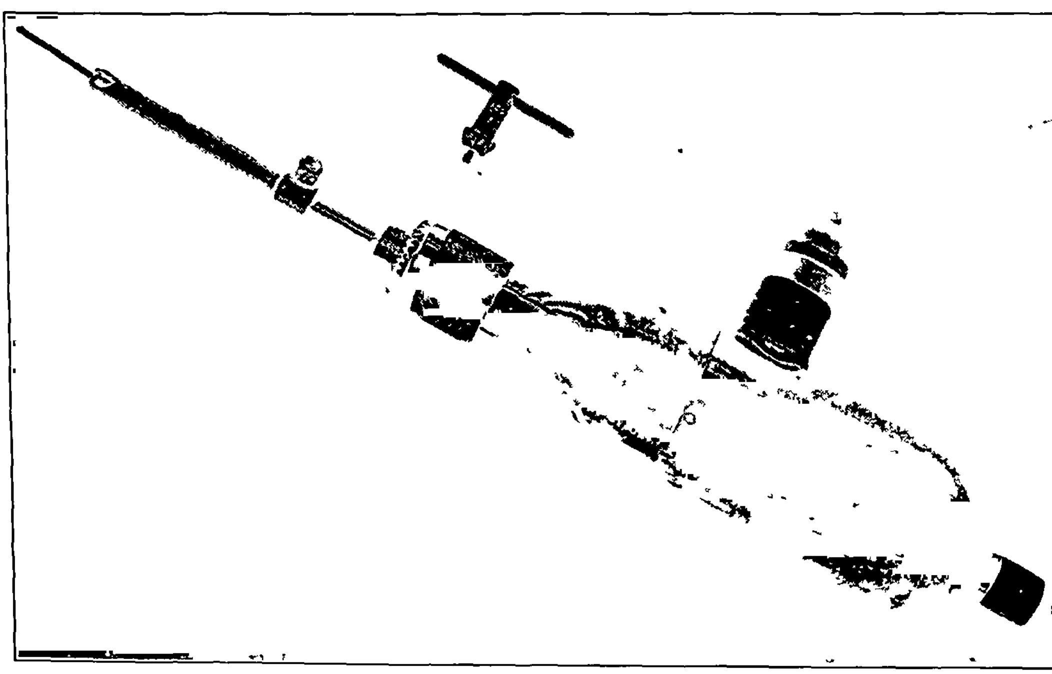

FIG 3

* Exhibited at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1946.

A SIMPLE LEG HOLDER FOR HIP-NAILING OPERATIONS

BY EDWARD PARNELL, M.D., ALBUQUERQUE, NEW MEXICO

In establishments where an abundance of willing and helpful hands are available, it is an easy matter to maintain a fractured hip in reduction by having an intern sit on a low stool and hold the leg firmly. An abundance of help is usually not available when needed, however; and, although the leg holder to be described is unable to think ahead or shift in position a few degrees on command, yet in the writer's experience it serves admirably. It can easily be made by an inexperienced carpenter, or by the surgeon himself.

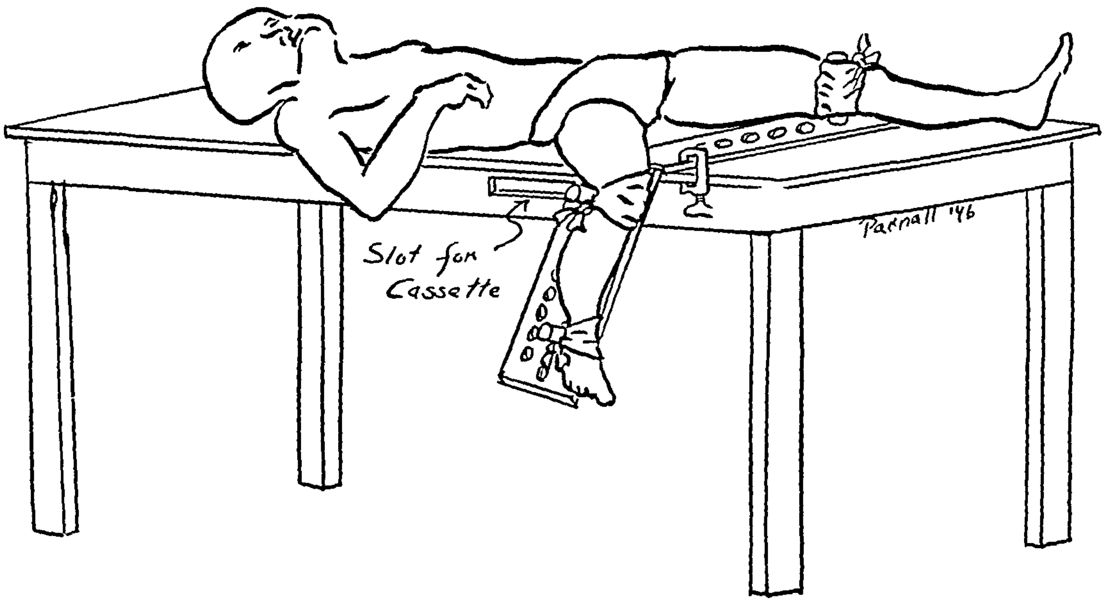

FIG. 1

Shows leg holder attached to wooden table, with patient in position.

It consists simply of two hardwood boards, about twenty-four to thirty inches long by nine inches wide, held together at one end by two small hinges. A sliding, adjustable prop is fixed to the under side, to maintain the boards at any desired angle with each other. The ordinary sliding fastener for holding storm windows open is suitable. Before the parts are assembled, one row of three-quarter-inch holes, three or four inches apart, is made in one board, and three rows of holes in the other. Three large pegs, to fit the holes, are made from sections of a broom handle.

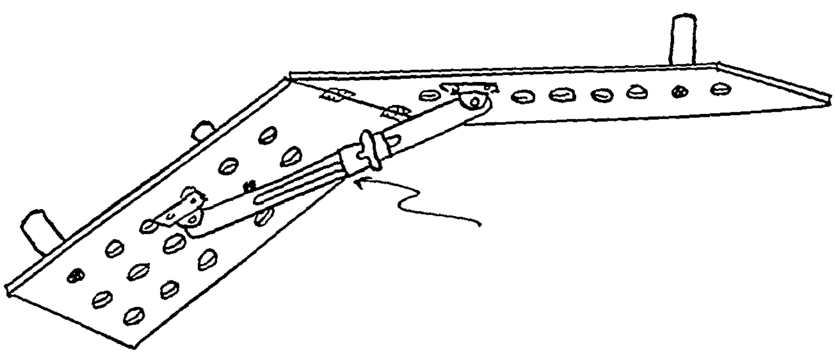

FIG. 2

View of under side of leg holder. Arrow points to adjustable bracket.

In use, the section with one row of holes is clamped to a table top with small C clamps. Any type of table will do, with or without a cassette tunnel. The writer uses a plain wooden table, with a built-in cassette slot (Fig. 1). The hip fracture is reduced, and the pegs, properly padded, are placed, one against the inner side of the knee on the sound side, to maintain abduction; one under the knee on the affected side; and one behind the ankle of the same side. The respective parts are then fixed to the pegs with bandages.

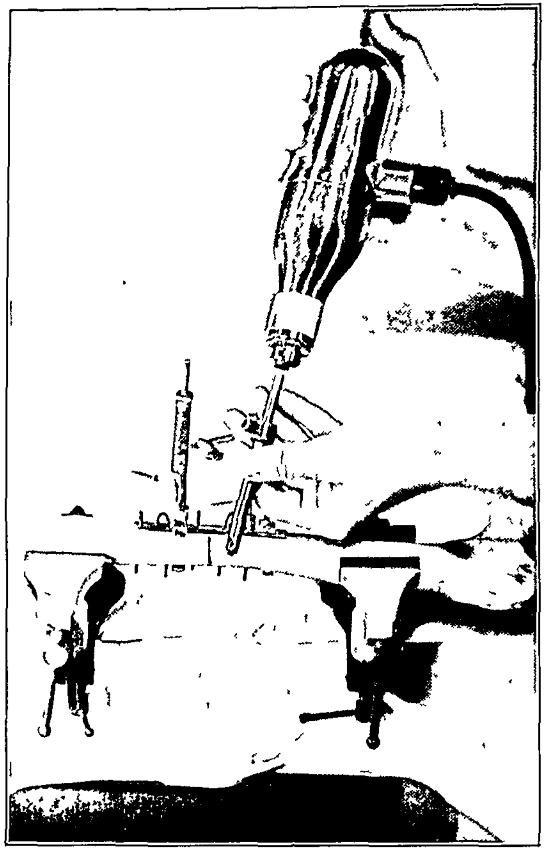

Fig. 7

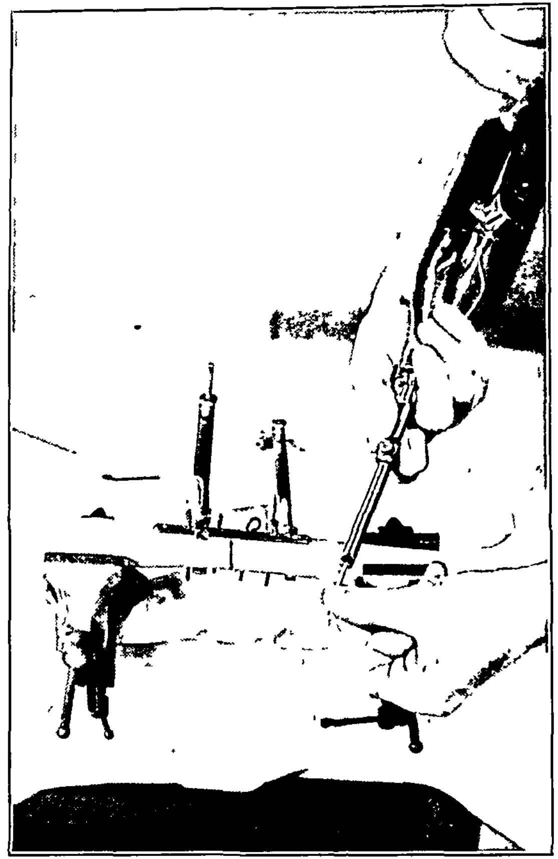

Fig. 8

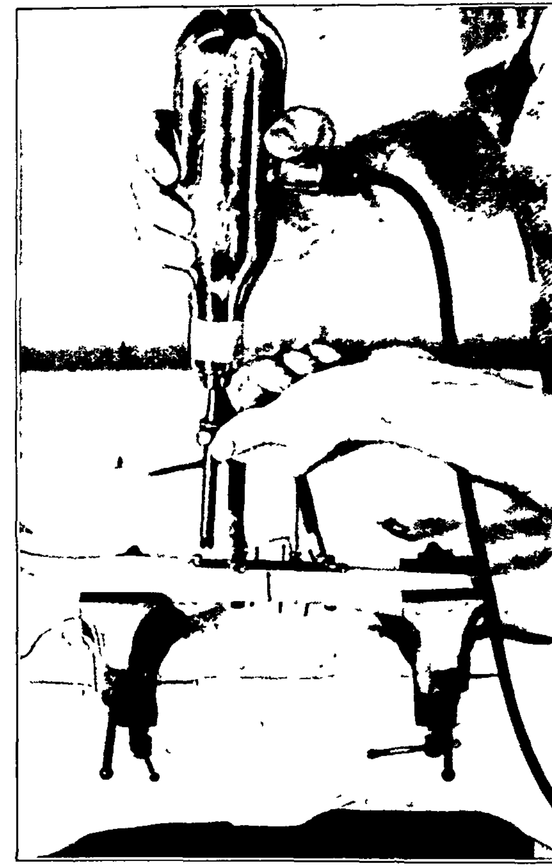

Fig. 9

Fig. 7: The drill is then removed, and the combination of screw holder and screw driver is fixed in the chuck.

Fig. 8: By loosening the thumb nut, the long sleeve is allowed to slide down on the screw driver. The screw is seated in its slot, the sleeve is pulled up so that the screw driver engages the screw, and the thumb nut is tightened. The speed of driving the screw can be determined by pressure of the foot on the rheostat.

Fig. 9: To release the screw holder, the thumb nut is loosened, permitting the screw driver to slide up in the sleeve, and the sleeve is slipped off the screw. The last few turns of the screw can either be made by the motor screw driver (slipping up the sleeve so that the screw driver projects beyond it) or by a hand screw driver.

THE FUNCTIONS AND ACTIVITIES OF THE COMMITTEE ON ARTIFICIAL LIMBS OF THE NATIONAL RESEARCH COUNCIL

A Preliminary Report *

BY PAUL E. KLOPSTEG, PH.D., SC.D., EVANSTON, ILLINOIS

Chairman, Committee on Artificial Limbs, National Research Council

This presentation is intended to constitute a general and practical informational review rather than an official report covering the functions, activities, and plans of the Committee on Artificial Limbs of the National Research Council.

The Committee on Artificial Limbs was established by the National Research Council following a conference that had been held in Chicago during the latter part of January 1945. This conference had been called at the instigation of The Surgeon General of the Army "to standardize artificial limbs", but this proved to be impossible for the kind of meeting that had been arranged. However, out of the meeting came the suggestion that a study of existing devices by a small group of engineers, physicists, and surgeons, with a view toward making improvements and perchance developing new devices, seemed clearly indicated. It will be recalled that the work of the Committee in its initial stages was made possible through a grant from the Office of Scientific Research and Development through the Committee on Medical Research, and that, with the gradual liquidation of the organization of the Office of Scientific Research and Development, the sponsorship was assumed by the War Department, joined later by the Veterans Administration. At the present time, these two agencies share in supporting this work, the Veterans Administration being the principal contracting agency.

The functions and responsibilities of the National Research Council, of which the Committee on Artificial Limbs is a part, are covered in the executive order of President Wilson, issued May 11, 1918. This order clearly limits its work to the scientific and technical fields. The functions of the Committee must be limited to these fields, if the kind of technical progress is to be made that we envisioned when we assumed responsibility for this work.

Since there was no ready-made group of laboratories that could undertake work on the problems outlined by the Committee, it became necessary to find organizations with laboratories and personnel that could undertake such assignments. Most of these workers had had no experience with artificial limbs, but they did have experience in research and development. Between the two alternatives of experience in limb-fitting only, or in research and development only, the latter was the more important. With this, the necessary indoctrination with reference to artificial limbs could be acquired by obvious procedures, with the help and advice of the Committee. Under the plan of operation followed by the Committee, the surgeons delineate the problems and the engineers undertake to find the most appropriate methods of solving them.

The first prosthetic device to be formally approved by the Committee, for use by the Veterans Administration and others, is the artificial arm developed by the Northrop Aircraft Company. Although this arm is still being tested, it satisfactorily meets the performance, strength, and hygienic requirements specified for this type of prosthesis. It has plastic construction, a plastic socket molded over a replica of the stump, and an elbow lock which can be made to mesh or disengage in a large number of positions by alternate pulls upon a control cord, attached to the shoulder harness. [A man who had had a bilateral amputation above the elbow demonstrated the above-elbow arm. An individual with a unilateral below-elbow amputation demonstrated a below-elbow prosthesis, equipped with a rotating wrist with step-up gears and locking mechanism.]

One matter which should be mentioned is the hope and expectation of everyone concerned with these problems that all amputees may benefit from whatever positive results have been and may be achieved through the work of the Committee. There seems no alternative to the conclusion that prosthetic devices will have to find their commercial outlet through the limb industry. Since veteran amputees constitute only about 5 per cent. of the total amputees in our population, it appears that at least 95 per cent. of the amputees will have to be accommodated through the limb industry, even though the Veterans Administration were to undertake the fitting and training of veterans through its own facilities. It seems indicated, therefore, that, if an agency or committee undertakes to develop plans by which improved artificial limbs shall be made available to amputees, that committee will have to give major consideration to questions of service and distribution to the large number of amputees whose disability is not connected with Military Service.

Several approaches to the more important research problems seem desirable. For the arm and hand,

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1947.

AN IMPROVED ROTATING STIRRUP FOR USE IN THE TREATMENT OF FRACTURES OF THE FEMUR WITH SKELETAL TRACTION

BY GERALD G. GILL, M.D., OAKLAND, CALIFORNIA

This article presents an improvement in the treatment of fractures of the femoral shaft with skeletal traction. The improvement consists in the use of a long rotating stirrup, extending from the level of pin insertion in the tibial tubercle to the sole of the foot. This method permits immediate and efficient exercise of the quadriceps muscle and of the knee, and has been used by the author since 1940.

APPARATUS

The apparatus is composed of three parts:

The first is a stainless-steel Steinmann pin, five thirty-seconds of an inch in diameter, preferably with a flat drill point.

The second portion is a Thomas splint or Army half-ring splint, of sturdy construction, with side bars three-eighths of an inch in diameter. Rigidity is necessary so that pressure may be placed on the fragments through slings or side pressure pads. The Army half-ring splint, which is less rigid than the Thomas splint, tends to spring together, and may be stabilized by the application of a curved metal clamp to join the two side bars (Fig. 1).

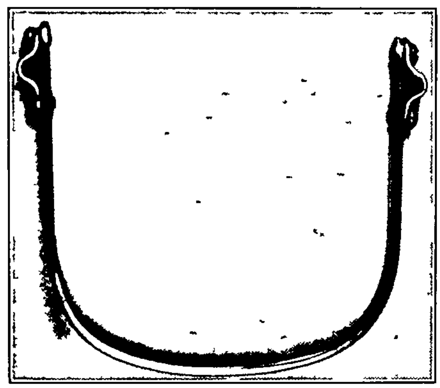

FIG 1
Metal spreader bar, used to stabilize the Army half-ring splint.

The long rotating stirrup differs from the usual Böhler rotating stirrup in that it extends from the tibial tubercle over the foot. It consists of two discs with set screws and holes for the Steinmann pin, together with the extension part of a cold-rolled steel, five thirty-seconds of an inch in diameter (Figs. 2-A and 2-B).

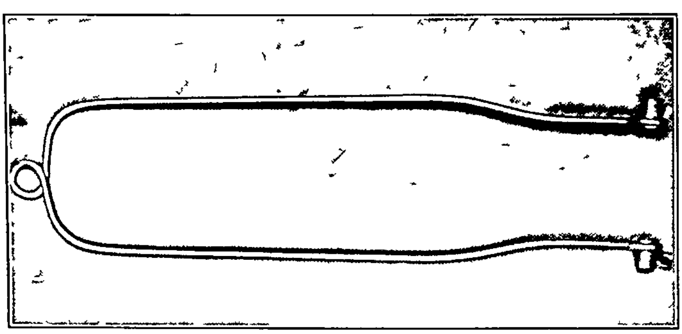

FIG 2-A
Long rotating stirrup

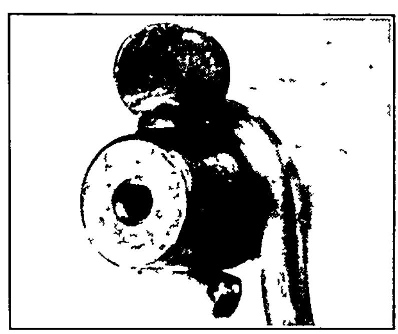

FIG 2-B
Detail of the disc portion of the rotating stirrup

METHOD AND TREATMENT

A Steinmann pin is drilled through the tibial tubercle, and the long stirrup is attached to the pin. The Thomas splint is then applied, the distal end of the splint being fixed directly to the crossbar. Slings are then applied to the splint.

Adjustments are made until the appearance of the thigh conforms closely to the

The complete success of the program, in which the Committee on Artificial Limbs is carrying the responsibility for the technical development, can, it seems to me, be achieved only through the cooperative efforts of those who recognize what the problems are. This obviously includes orthopaedic surgeons to the extent that they will take an enthusiastic part, not merely in supporting such a program as that being conducted by our Committee, but also in efforts to carry the work further, as indicated. With more than 400,000 amputees in the United States alone, such efforts appear exceedingly worth while. Aside from any material considerations, there would be in store for those who participate great satisfaction in alleviating both physical and mental discomforts and in helping unfortunates toward regaining, in greatly increased measure, the ability to engage in normal activities.

CHARLES FAIRBANK PAINTER

1869–1947

Charles F. Painter of Boston died on January 6, 1947. Descended from an old Virginia family, he was born at Grand Haven, Michigan, the son of a clergyman. He went to school in Great Barrington, Massachusetts, going on from there for one year to Williams College and then to Johns Hopkins University. He obtained his medical education at the Harvard Medical School, having been graduated in 1895 with such men as Elliott Joslin, Amory Codman, and Harvey Cushing. He then became a Surgical House Officer at the Massachusetts General Hospital. There he became interested in orthopaedic surgery, which he practised thereafter up to the day of his death.

Early in his career he became interested in medical literature, later devoting much of his time to it. In 1901 he was co-author, with Dr. Goldthwait and Dr. Osgood, of the book, *Diseases of the Bones and Joints*.

At first, he taught both at Harvard and Tufts Medical Schools. Concentrating his attention at Tufts, he became, in 1913, Dean of the Medical School and Professor of Orthopaedic Surgery, positions which he held until he resigned in 1922.

He served for many years as Chief Orthopaedic Surgeon to the Carney Hospital; and, during World War I, he served as Orthopaedic Surgeon to the Chelsea Naval Hospital. At one time he was Orthopaedic Surgeon to the Robert Breck Brigham Hospital and the House of the Good Samaritan. In the last years of his practice he held the position of Orthopaedic Surgeon to the Beth Israel Hospital and the Massachusetts Women's Hospital. At one time he was Professor of the History of Medicine at Tufts Medical School, a subject in which he was greatly interested. For many years he was a member of the Medical Committee of the Industrial School for Crippled and Deformed Children.

In 1899 he was elected to membership in The American Orthopaedic Association, becoming its President in 1916.

As a member of the Editorial Committee of The American Orthopaedic Association from 1908 through 1914, Dr. Painter gave freely of his time and interest to *The Journal*, the publication of which

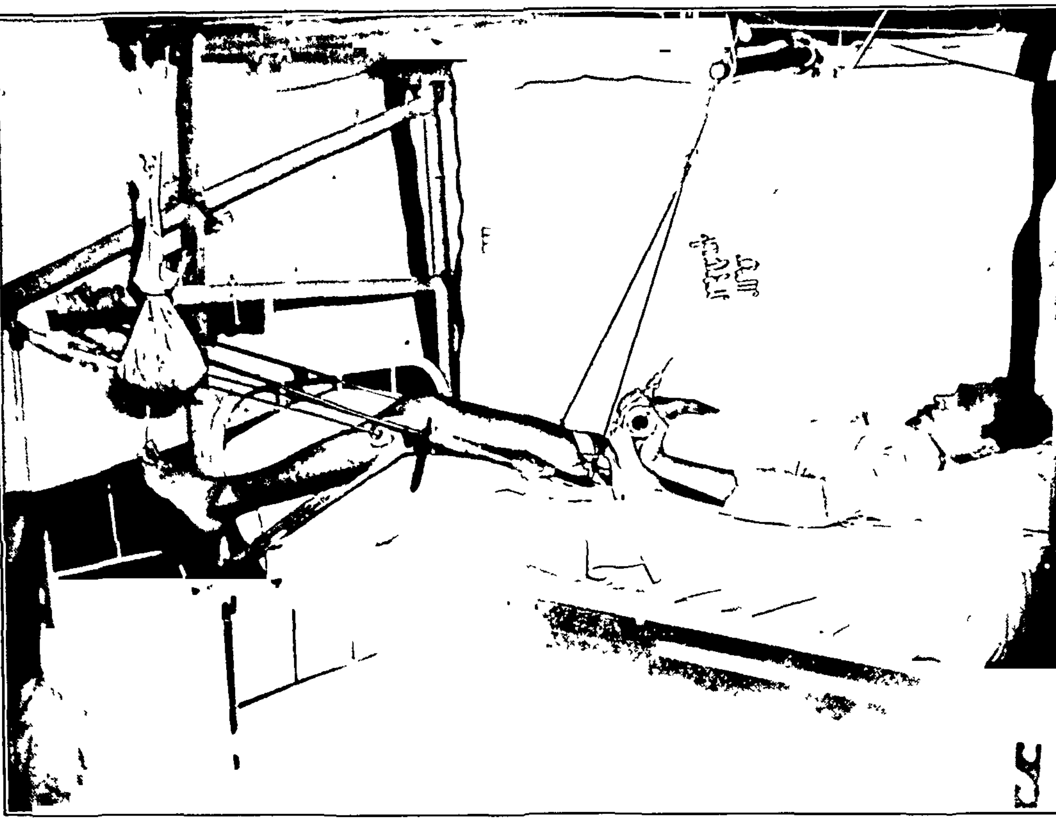

FIG. 3-B

Shows knee flexion possible with traction being maintained. (*Photograph by U. S. Army Signal Corps.*)

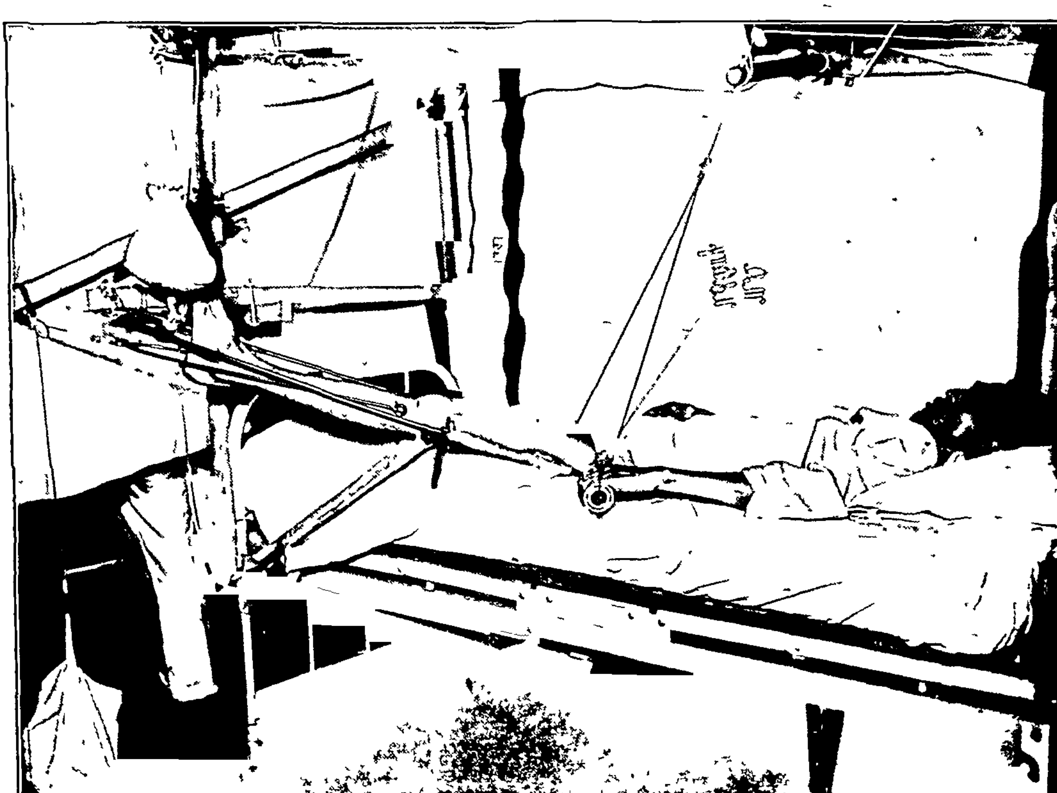

FIG. 3-C

Patient is shown, actively exercising his quadriceps. (He is able to lift the leg against gravity eight weeks after the fracture.) (*Photograph by U. S. Army Signal Corps.*)

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The American Orthopaedic Association will be held at Hot Springs, Virginia, June 27, 28, 29, and 30, 1947, under the presidency of Dr. LeRoy C. Abbott. Headquarters will be at The Homestead Hotel.

The tentative program as prepared by the Program Committee is as follows:

FRIDAY, JUNE 27

Morning Session

The Primary Suturing of Compound Fractures Including Internal Fixation, Skin Graft, Compression Dressings and Other Salient Features.
Arthur Davis, M.D., Erie, Pennsylvania.

The Management of Venous Thrombosis of the Extremities.
Daniel C. Elkin, M.D., Emory University, Georgia (by invitation).

A New Approach in the Surgical Treatment of Lymphoedema of the Extremities.
H. B. Macey, M.D., Temple, Texas.

Bone Marrow and Blood Studies in Multiple Myeloma and Certain Other Skeletal Lesions.
Ernest H. Falconer, M.D., San Francisco, California (by invitation).

Bone and Joint Changes in Hemophilia.
Ralph K. Ghormley, M.D., Rochester, Minnesota.

Internal Fixation for Lumbar Spinal Fusion Operations.
Don King, M.D., San Francisco, California.

Noon: Executive Session.

Afternoon Session

The Painful Shoulder—Observations on the Role of the Tendon of the Long Head of the Biceps Brachii in its Causation.
Harold H. Hitchcock, M.D., Oakland, California;
C. H. Bechtol, M.D., Oakland, California (by invitation).

A Preliminary Report on the Evaluation of Modifications of the Bankart Procedure for Recurrent Dislocations of the Shoulder Joint.
Joseph B. Josephson, M.D., Philadelphia, Pennsylvania (by invitation);
Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania.

Extra-Skeletal Ossification Simulating Sarcoma.
Howard Hatcher, M.D., Chicago, Illinois.

New Method for Fusion of Ununited Fractures of the Carpal Bones.
Paul B. Steele, M.D., Pittsburgh, Pennsylvania.

The Cineplastic Method for Upper-Extremity Amputations.
Rufus H. Alldredge, M.D., New Orleans, Louisiana.

Pseudarthrosis in the Lumbosacral Spine.
Mather Cleveland, M.D., New York, N. Y.;
David M. Bosworth, M.D., New York, N. Y.

SATURDAY, JUNE 28

Morning Session

The Management of Comminuted Fractures of the Distal End of the Humerus Involving the Elbow Joint.
John L. McDonald, M.D., Toronto, Ontario, Canada.

Fractures of the Capitellum Humeri.
John C. Wilson, M.D., Los Angeles, California.

Homografts in Orthopaedic Surgery.
Myron O. Henry, M.D., Minneapolis, Minnesota.

Congenital Pseudarthrosis: Follow-up Study after Massive Bone-Grafting.
Harold B. Boyd, M.D., Memphis, Tennessee.

Surgical Treatment of Intractable Plantar Warts.
James A. Dickson, M.D., Cleveland, Ohio.

A METHOD OF OFFSETTING THE EXTERNAL ROTATION OF LIMBS IN TRACTION

BY ROBERT M. ROSE, M.D., NEW ORLEANS, LOUISIANA

From the Department of Orthopaedics, Louisiana State University Medical School and the Louisiana State Charity Hospital, New Orleans

In treating fractures of the hip region by traction, it is often found that the leg and foot fall into a position of external rotation. This may be difficult to overcome, and permanent deformity will persist if healing occurs while the limb is in this position.

This tendency of a limb to rotate externally may be overcome by utilizing the unwinding effect of the leg wrapping, through traction applied to it, as shown in Figure 1.

FIG. 1

When the elastic bandage is applied over the adhesive used for the skin traction, the bandage is wrapped in such a manner that it comes from beneath the leg to the outer side and then up over the anterior surface. The limb is wrapped from the ankle to just below the knee, and then distally to just below the belly of the calf. About six feet of bandage should remain. This is doubled, so that the free end is caught beneath the succeeding turns. The doubled portion of the bandage should have at least two full turns about the leg, and the free end should come up on the outer side. A triangular wire frame is then slipped through the loop of bandage, and two or three pounds of traction is placed upon it. This rotation force will be found to balance the leg in a normal position.

There are two precautions to be observed: First, the last turn must not be allowed to pass over the peroneal nerve, where it crosses the fibula, or the patient will complain of pain in his foot; and, second, the doubled traction loop should be of sufficient length to prevent its being pulled out.

This is a simple expedient which has been used effectively in over thirty cases. It overcomes the undesirable tendency of limbs in traction to rotate externally, and does not complicate or interfere with other traction.

AMERICAN BOARD OF ORTHOPAEDIC SURGERY

The American Board of Orthopaedic Surgery will hold its next examination—Part II—in Chicago, *Illinois*, on *January 22 and 23, 1948.*

The deadline for receipt of completed formal application and application fee is September 15, 1947. Letters of request and applications received after this date cannot be accepted.

Correspondence and applications related to Part II of the examination should be sent to the Secretary of the American Board of Orthopaedic Surgery, Dr. Francis M. McKeever, 1136 West 6th Street, Los Angeles 14, California.

The American Rheumatism Association pursuant to its plans, which were interrupted by the War, to hold a Congress of La Ligue Internationale contre le Rhumatisme in the United States during 1940, is now announcing to all members its desire to sponsor an International Congress for Rheumatic Disease in the United States in 1949. The time and place will be determined later, but will be approximately contemporaneous with the Annual Convention of the American Medical Association.

The desperate and continued need for American publications to serve in the physical and intellectual reconstruction abroad has been made apparent by appeals from scholars in many lands. **The American Book Center for War Devastated Libraries** is making a renewed appeal for American books and periodicals,—for technical and scholarly books and periodicals in all fields and particularly for publications of the past ten years. Especially welcome are complete or incomplete files of *The Journal.* All contributions should be shipped to the American Book Center, care of The Library of Congress, Washington 25, D. C., freight prepaid. Those interested may write to the Center for further information.

The University of Rochester School of Medicine and Dentistry in cooperation with the New York State Health Department and the National Foundation for Infantile Paralysis announces the establishment of a rehabilitation hospital for spastic children. This hospital will serve as a pilot plant for investigation and treatment of cerebral palsy for the state and nation. It is expected that the hospital will be located in LeRoy, New York, where an extensive tract of land has been offered to the University, with a spacious residence which can readily be adapted to use as a hospital. The project will serve as a center of training for the various types of personnel concerned with the treatment and care of cerebral palsy patients throughout the State of New York and the nation. It is hoped that the hospital will be in operation by next summer.

The Committee on Artificial Limbs of the National Research Council is supporting a program of research and development in the fitting of artificial limbs with suction sockets for above-the-knee amputees. The suction method of securing the artificial leg to the stump, although the subject of a United States patent in 1863, was apparently not used extensively until about seventy years later, when German limb makers began fitting such limbs to patients. Many successful cases were observed in Germany in 1946 by members of the Army Surgeon General's Commission on Amputations and Prostheses.

The Committee has secured the cooperation of a number of limb manufacturers in various parts of the country in exploring the problem. By experimenting in several geographical locations it is hoped to determine the effects of climate on the wearing of such limbs. Each manufacturer will have available as consultant an orthopaedic surgeon appointed by the Committee. All technical information in possession of the Committee is being made available to the manufacturers.

A preliminary report will be prepared by the Committee as soon as sufficient data have been obtained and analyzed. The Committee has not approved the method for general use. Patients to be fitted should be selected only under the supervision of a competent surgeon, and they should be assured that the limb fitter is thoroughly informed about the fitting and construction of suction sockets.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The *Fourteenth* Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 26, 27, 28, 29, and 30, 1947, under the presidency of Dr. J. E. M. Thomson. The Convention was the largest in the history of The Academy. The Audio-Visual Program, under the chairmanship of Dr. Charles N. Pease, was well arranged and attracted large audiences. The

The patient is now ready to undergo whatever hip-fixation operation the surgeon intends to perform, such as that involving the use of the Smith-Petersen nail.

It has been the habit of the writer to carry out this procedure, using the apparatus described, with only the assistance of a nurse. His sterile, gowned arms are covered with sterile ether stockings until reduction of the fractured hip has been effected; then the stockings are discarded and he proceeds with the driving in of the Smith-Petersen nail.

A MODIFICATION OF THE BLADE-PLATE FOR THE TREATMENT OF INTERTROCHANTERIC FRACTURES OF THE HIP

BY ROBERT GLEN BRONSON, M.D., MINNEAPOLIS, MINNESOTA

From the Orthopaedic and Fracture Service, Minneapolis General Hospital

One of the problems associated with the use of the blade-plate has been that of introducing the blade in such a way as to place it accurately in a predetermined position in the femoral neck, particularly in the anteroposterior plane.

A simple solution of that problem, which has proved consistently satisfactory, is the modification of the blade-plate shown in Figure 1.

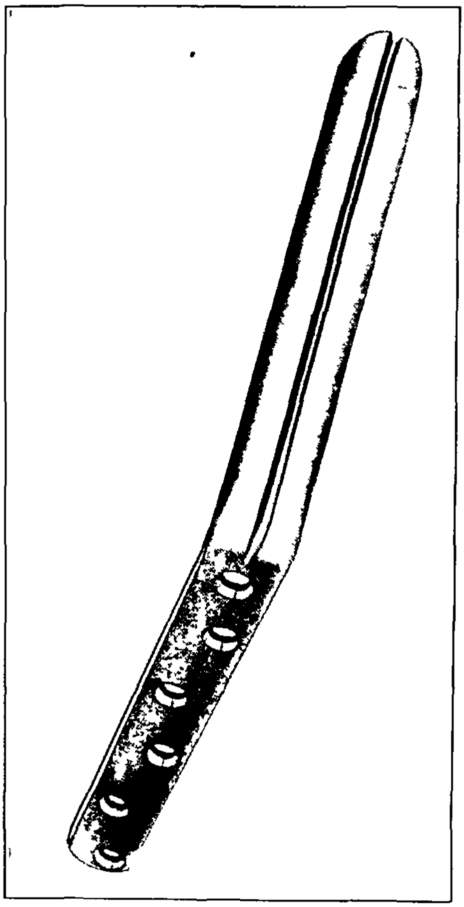

FIG. 1

A longitudinal groove is made down the middle of the superior surface of the blade; the depth of the groove is approximately three-fourths the diameter of the guide wire to be used, and its width just great enough to allow easy motion of the guide wire through it. Heavy Kirschner wire is used for the guide wire, which is graduated in centimeters to allow a relatively accurate determination of the necessary blade length.

The guide wire is introduced through the center of the narrow, transverse linear defect, chiseled in the lateral cortex beneath the greater trochanter.

The blade is then placed beneath the guide wire which fits snugly into the groove along the entire length of the blade, the wire being held in the groove by the pressure on it from above by the superior edge of the transverse defect, through which the blade is to be driven. The blade is driven in with a simple lug driver, in order that the blade may be perfectly free to follow the direction of the guide wire.

Afternoon Session

Results of Recent Studies and Experiments Concerning Internal Fixation of Fractures with Metals.
Charles S. Venable, M.D., San Antonio, Texas;
Walter D. Stuck, M.D., San Antonio, Texas.
Discussion: J. Albert Key, M.D., St. Louis, Missouri;
Leonard Peterson, M.D., Washington, D. C.;
Clay Ray Murray, M.D., New York, N. Y.;
Walter D. Stuck, M.D.

The Iliac Apophysis: An Invaluable Sign in the Management of Scoliosis.
Joseph C. Risser, M.D., Pasadena, California.
Discussion: William H. Von Lackum, M.D., New York, N. Y.;
Francis E. West, M.D., San Diego, California;
Alvia Brockway, M.D., Los Angeles, California;
Joseph C. Risser, M.D.

Anterior Tibial Tendon Transposition in Recurrent Congenital Club-Foot.
George J. Garceau, M.D., Indianapolis, Indiana;
K. R. Manning, M.D., Indianapolis, Indiana.
Discussion: Hiram Kite, M.D., Atlanta, Georgia;
Charles W. Peabody, M.D., Detroit, Michigan;
Eben W. Fiske, M.D., Pittsburgh, Pennsylvania;
George J. Garceau, M.D.

Arthroplasty of the Hip for Congenital Dislocation in Children.
Paul C. Colonna, M.D., Philadelphia, Pennsylvania.
Discussion: C. H. Crego, M.D., St. Louis, Missouri;
C. R. Rountree, M.D., Oklahoma City, Oklahoma;
Paul C. Colonna, M.D.

Coxa Plana.
M. B. Howorth, M.D., New York, N. Y.
Discussion: A. Bruce Gill, M.D., Philadelphia, Pennsylvania;
M. N. Smith-Petersen, M.D., Boston, Massachusetts;
George Hammond, M.D., Sayre, Pennsylvania;
M. B. Howorth, M.D.

WEDNESDAY, JANUARY 29

Morning Session

Growth of the Lower Extremity Affected by Anterior Poliomyelitis; Experiences in Equalizing Discrepancies by Epiphyseodesis.
William T. Green, M.D., Boston, Massachusetts;
Margaret Anderson, M.S., Cambridge, Massachusetts (by invitation).

The Effect of Roentgen Irradiation on Epiphyseal Growth. Experimental Studies upon the Dog.
J. A. Reidy, M.D., Boston, Massachusetts;
Joseph S. Barr, M.D., Boston, Massachusetts;
James R. Lingley, M.D., Boston, Massachusetts;
Edward A. Gall, M.D., Boston, Massachusetts.
Discussion of the foregoing papers:
Edward L. Jenkinson, M.D., Chicago, Illinois (by invitation);
Frederic C. Bost, M.D., San Francisco, California;
J. Warren White, M.D., Greenville, South Carolina;
Dallas B. Phemister, M.D., Chicago, Illinois;
William T. Green, M.D.

Presidential Address.
J. E. M. Thomson, M.D., Lincoln, Nebraska.

Subtrochanteric Osteotomy in the Mobile Hip Controlled by the Well-Leg Traction Splint.
J. Warren White, M.D., Greenville, South Carolina;
J. H. Turkell, M.D., Greenville, South Carolina.
Discussion: Herman C. Schumm, M.D., Milwaukee, Wisconsin;
Robert G. Packard, M.D., Denver, Colorado;
J. Warren White, M.D.

Our Experience in Treatment of Fracture of the Neck of the Femur.
José Luis Bado, M.D., Montevideo, Uruguay (by invitation).

designs are being prepared, utilizing several sources of power. The Committee hopes to develop a lightweight hand, at least as useful as the hook, with a satisfactory natural appearance. In addition, it hopes to make improvements in cosmetic covering. Several developments in the field of prostheses for the arm and hand are in progress. One of them is a hand which is operated by hydraulic cylinders. The power supply for the hand comes from an ingeniously designed pump mechanism, which is operated by the foot. [A unilateral amputee demonstrated a working model of this hydraulic mechanism, attached to a miracle hand.]

Waterproof foot and ankle constructions of light weight are being developed. Several approaches to the problem of the knee lock for an artificial leg include both mechanical and hydraulic methods with a variety of controls. Exhaustive fundamental studies for all of these problems were made on the mechanics of walking and on the hand and arm motions required in daily life. A recent design of a hydraulic knee lock, not yet in its perfected state, has been developed by one of our subcontractors. [This new hydraulic knee lock was demonstrated to show how closely natural walking had been simulated.]

In a phase of its cooperation with the limb industry, the Committee is engaged in an extensive program concerned with the development and reintroduction of the suction socket, originally an American invention at the time of the Civil War and widely used abroad for the past few years. The Army Surgeon General's European Commission on Amputations and Prostheses, of which Dr. Leonard T. Peterson, Dr. Rufus Alldredge, and the speaker were members, made an extended tour through European countries last spring to study and appraise the prosthetic devices being used by other peoples of the world. The suction-socket method of holding an artificial leg to a stump by means of a slight vacuum inside the socket was one of the important developments found in Germany. This was pointed out in the "Report on European Observations". Cooperating with the Committee on Artificial Limbs in its program of developing the suction socket are a dozen concerns, comprising commercial limb makers and certain other subcontractors to the Committee. Extensive service tests and accumulation of scientific data are in progress. An orthopaedic surgeon has been appointed by the Committee to act as a consultant to each of the limb makers throughout the country who are participating in this program. A surgeon and limb fitters on the staff of the Committee are also available for advice and assistance. Based on the experience thus far, there is every indication that the suction-socket method of fitting will prove successful for selected cases. [An above-knee amputee demonstrated an artificial leg, equipped with a suction socket. No harnesses were used in conjunction with this artificial limb.]

The cineplastic method, creating skin-lined tunnels through muscles that control the motion of the arm and hand, is being studied. This was observed principally in Munich, as done by Professor Max Lebsche. The program involves surgery by the latest techniques, as well as the development of improved prostheses. This procedure gives great promise of improving the dexterity of certain types of amputees. Dr. Alldredge, with the cooperation of the office of The Surgeon General and of Dr. Rex L. Diveley, has made a motion picture of two of the cineplastic operations, which has already been shown at this Meeting.

One model of the arm and hand prosthesis which has been developed for cineplastic amputees is in the first stage of development. [The model was demonstrated.]

In the time allotted to this presentation, it has been possible to give only a few of the high lights of the extensive program of the Committee on Artificial Limbs. The Committee is keenly aware that, no matter how successful the technical aspects of the work may be, the ultimate objectives will not have been attained until the new and improved devices become generally available, through commercial channels, to the thousands of amputees who might benefit by having them. The ways and means of accomplishing this are not the responsibility of the Committee on Artificial Limbs, since under the National Research Council its functions are purely technical.

Several other problems that are not strictly technical, but nevertheless highly important, have come to the attention of the Committee in the course of this work. I recognize the possibility that this body of orthopaedic surgeons is aware of them, but I do not want to let the opportunity pass of emphasizing their importance.

It seems, to a layman like myself, unfortunate that, after the amputation has been accomplished successfully, the amputee in most cases is no longer the concern of the surgeon. It seems equally unfortunate that, after recovery, he may find himself in the hands of a limb fitter whose knowledge of the anatomy and fundamental mechanics of walking are far from profound. Much remains to be done for the unfortunates who have lost limbs, to help each in obtaining the best possible prosthesis for his particular case and to see that he is given every possible assistance in developing the use of the prosthesis so that it may approximate the normal functions as closely as its technical limitations permit. I am not prepared to say whose obligation it is to supply what is obviously missing. There is a suggestion of a possible solution, however, in observations which members of The Surgeon General's Commission made in Europe, where in some places orthopaedic surgeons concerned themselves exclusively with the proper fitting of limbs and training of amputees. One fact is particularly clear: We are not fulfilling our responsibility towards the amputee, unless we do more than provide him with a mechanical appliance that will substitute for a normal member.

Discussion of the foregoing papers:
Sterling Bunnell, M.D., San Francisco, California;
George Phelan, M.D., Cleveland, Ohio (by invitation);
L. G. Howard, M.D., Boston, Massachusetts;
Walter Graham, M.D.

Executive Sessions were held on Tuesday noon and on Thursday noon. The Annual Dinner was held on Wednesday evening. Brief addresses were given by General Hawley, and by the foreign guests: Professor Mudr. Bedřich Frejka of Czechoslovakia, Professor José Luis Bado of Uruguay, and Sir Reginald Watson-Jones of London. The presidential medallion was presented to President Thomson by Past-President Mumford.

At this dinner the awards for scientific exhibits were made, as follows:

Class I: For Originality of Presentation.

1. John J. Fahey, M.D., and Michael De Cosola, M.D., Evanston, Illinois, "Pathology of the Shoulder after Experimental Dislocation at Autopsy".
2. J. Warren White, M.D., Greensboro, South Carolina, "Automatic Reciprocating Vacuum Dermatome".
3. Dana Street, M.D., Memphis, Tennessee, "Plastic Braces".

Class II: For Scientific Value.

1. Joseph S. Barr, M.D., Boston, Massachusetts, "The Control of Epiphyseal Growth by Roentgen Irradiation".
2. Robert M. O'Brien, M.D., St. Louis, Missouri, "Polyostotic Fibrous Dysplasia of Bone".
3. Paul C. Colonna, M.D., and Roy Peck, M.D., Philadelphia, Pennsylvania, "Metastatic Lesions in Bone".

Class III: For Clinical Value.

1. J. A. Dickson, M.D., and Royston Miller, M.D., Cleveland, Ohio, "High Geometric Osteotomy for Ununited Fractures".
2. J. E. Milgram, M.D., Brooklyn, N. Y., "Technique for Operative Restoration of Extensor Gliding Mechanisms of the Major Joints".
3. Austin T. Moore, M.D., and Joseph E. Brown, M.D., Columbia, South Carolina, "The Unstable Spine and Disc Protrusions: Treatment with Self-Locking Prop Bone Graft".

The following awards were also presented for Audio-Visual presentations:

Surgeon General Norman T. Kirk, M.C., U. S. A., for films produced under his direction by th War Department—Certificate of Merit.
Paul C. Colonna, M.D., for his film, "Arthroplasty of the Hip for Congenital Dislocation i Children"—Certificate of Merit.
Ralph K. Ghormley, M.D., for his film, "Chondromatosis of the Knee"—Honorable Mention
Clay Ray Murray, M.D., for his film, "Technique—Open Reduction—Long Bone Fracture"—Honorable Mention.

At this dinner diplomas were presented to the following newly elected Fellows by President J. E. M Thomson and Dr. J. Warren White, Chairman of the Membership Committee.

Carroll Omar Adams, M.D., Mason City, Iowa
W. Compere Basom, M.D., El Paso, Texas
Ernst W. Bergmann, M.D., New York, N. Y.
Ernest H. Bettmann, M.D., White Plains, New York.
Joseph H. Boland, M.D., Atlanta, Georgia
David Molley Cameron, M.D., El Paso, Texas
Parker C. Carson, M.D., Springfield, Massachusetts
Santino J. Catanzaro, M.D., Mt. Vernon, New York
M. Melvin Clark, M.D., Rochester, New York
Bernard N. E. Cohn, M.D., Denver, Colorado
John Joseph Crowley, M.D., Lynn, Massachusetts
Joe B. Davis, M.D., Portland, Oregon
Eliot M. Friedman, M.D., Utica, New York
Kilian F. Fritsch, M.D., St. Louis, Missouri
William Edwin Gazeley, M.D., Schenectady, New York
Gerald George Gill, M.D., Oakland, California
Walter Henry Hagen, M.D., Billings, Montana
Harry B. Hall, M.D., Minneapolis, Minnesota
George B. Higley, M.D., Memphis, Tennessee
Ben L. Hull, M.D., Altoona, Pennsylvania
Clarence William Hullinger, M.D., Springfield, Ohio

CHARLES FAIRBANK PAINTER

was then the function of that Committee. From 1937 to 1944, he was a member of the Board of Associate Editors; and for seven months following the death of Dr. Murray S. Danforth, in June 1943, he served as Acting Editor of *The Journal of Bone and Joint Surgery.* During all these years he contributed richly to the growth and development of *The Journal,* both in the editorial work and later as administrator and counsellor.

Besides all these activities, he became Librarian of the Boston Medical Library, a position he held for eight years. In 1940 he assumed the editorship of the Year Book of Industrial and Orthopedic Surgery, which became valuable as a critical review of each year's important literature on these subjects. His choice of subjects for review, clearness of expression, fair and judicial comments on the new and controversial reports were of great value, coming as they did from one who had had so many years of contemplative and surgical experience.

As a person he was delightful,—modest, with a strong sense of humor, one who was a good companion and full of common sense. He will be missed by his many friends and associates. Orthopaedic surgery has lost a great scholar.

Current Literature

PENICILLIN. ITS PRACTICAL APPLICATION. Under the General Editorship of Professor Sir Alexander Fleming, M.B., B.S., F.R.C.P., F.R.C.S., F.R.S. Philadelphia, The Blakiston Company, 1946. $7.00.

The volume consists essentially of a series of articles designed to present penicillin therapy as practised in Great Britain during the first half of 1946. It gives the views of many experienced and eminent men who have worked with penicillin in Great Britain, some of whom may not be known to American physicians. It might have been greatly modified if written by American authors, by virtue of the wider application and the larger doses used, owing to the more plentiful supply and lower cost of the agent in this country. This is to be expected, as Fleming points out in the Preface, where he states: "The guiding rule is to give enough; it is much better to give more than enough than to give too little".

There are introductory chapters on general aspects—namely, history and development, chemistry and manufacture, pharmacy, pharmacology, bacteriological controls, and methods of administration—all written in simple and readable language. There follow eighteen chapters on the use of penicillin in various specific diseases or in general types of conditions and situations. More than half of them refer to surgical uses. Of particular interest to readers of *The Journal* are the separate chapters dealing with prophylactic use, wounds and gas gangrene, burns and plastic surgery, orthopaedic surgery and fractures, osteomyelitis, and hand infections. As might be expected, some of the contributors have leaned rather heavily on their own experiences and those of their British confreres, and have omitted reference to, or even any consideration of, the many valuable American contributions. The reader may, therefore, find many points of view different from those to which he has become accustomed from reading the American literature. Many of the chapters, however, are personal and intimate presentations, and they are ver readable and highly practical. They should be of considerable value as a reference guide to physiciar and surgeons in many fields, perhaps a little more to British than to Americans.

A concluding chapter on "Penicillin and the General Practitioner" gives a simple and brief surve with a classified bibliography to supplement the references quoted in the individual chapters.

CONDUCTION ANESTHESIA. Clinical Studies of George P. Pitkin, M.D., F.A.C.S., F.I.C.A. Edited b James L. Southworth, M.D., and Robert A. Hingson, M.D. Philadelphia, J. B. Lippincott Compan 1946. $18.00.

The need for a book which would give the principals and techniques of regional anaesthesia has bee felt for some time. The present volume, based upon the study and experience of Dr. George P. Pitkin includes not only the material collected and prepared by him, but also chapters by the editors and b eight collaborators on phases of the subject upon which each is especially qualified to write. The resul is a gratifyingly complete treatise on the subject.

Approximately the first quarter of the book consists of a discussion of the anatomy of the nervou system. This section contains many illustrations, of which those of the innervation of the abdomina viscera are perhaps the most noteworthy. The ensuing chapters on the pharmacology, principles, and instruments of conduction anaesthesia are of great value to anyone who contemplates employing the method.

The remainder of the book consists of descriptions of the technique of specific blocks, and the indications for their use. These descriptions seem to the reviewer admirably clear and easy to follow. They are supplemented by many exceptionally fine illustrations.

On the whole, this book is a notable addition to the literature, and will be of great value to surgeons and anaesthesiologists alike.

INJURIES OF THE KNEE JOINT. I. S. Smillie, O.B.E., M.B., F.R.C.S.(Ed.), F.R.F.P.S. Baltimore, The Williams and Wilkins Company, 1946. $9.00.

Although Smillie's extensive experience with disorders of the knee joint was gained primarily while he was in charge of an orthopaedic unit in a Base Hospital during World War II, the injuries he describes are, with the exception of war wounds, those which civilians incur in the course of their activities.

The book contains a comprehensive survey of the various injuries to which the knee is heir, as well as a discussion of their treatment—including the technique of operative repair and after-care—and the results. By far the greatest emphasis is placed upon injuries of the menisci, which are the most common derangements of the knee joint. The various meniscus operations are described, with their technique and complications.

In general, the book is written from a practical, rather than a theoretical, point of view. It is clear and concise, and the various lesions and operative procedures mentioned are illustrated unusually well.

Operation to Correct the Valgus Deformity Resulting from Pott's Fracture.
E. Bishop Mumford, M.D., Indianapolis, Indiana.

An Evaluation of Penicillin Therapy in Acute Hematogenous Osteomyelitis.
W. A. Altemeier, M.D., Cincinnati, Ohio (by invitation).

Acute Hematogenous Osteomyelitis. A Study on Treatment.
I. William Nachlas, M.D., Baltimore, Maryland.

SUNDAY, JUNE 29

Morning Session

Certain Features of the Mechanics of the Hip Joint.
Verne T. Inman, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.D., San Francisco, California (by invitation).

Cartilaginous Cup Arthroplasty.
John R. Moore, M.D., Philadelphia, Pennsylvania.

Muscular Torticollis.
Fremont A. Chandler, M.D., Chicago, Illinois.

The Nitrogen Content of Bone. A Laboratory Study.
L. J. Strabino, M.D., Wilmington, Delaware (by invitation);
A. R. Shands, Jr., M.D., Wilmington, Delaware.

Experimental Intervertebral-Disc Lesions.
J. Albert Key, M.D., St. Louis, Missouri;
Lee T. Ford, M.D., St. Louis, Missouri (by invitation).

Overlap Bone Operation for Malunions and Persistent Non-Unions of Fractures of Both Bones of the Forearm.
J. Warren White, M.D., Greenville, South Carolina.

Presidential Address.
LeRoy C. Abbott, M.D., San Francisco, California.

MONDAY, JUNE 30

Morning Session

Follow-up Studies in Congenital Dislocation of the Hip.
Alan DeForest Smith, M.D., New York, N. Y., *Chairman.*

Embryology of the Hip with Etiology and Pathology of Congenital Dislocation.
Carl E. Badgley, M.D., Ann Arbor, Michigan.

Congenital Dislocation of the Hip with Treatment Prior to the Age of Eight Years.

Report of Results of Treatment of Congenital Dislocation of the Hip in Infancy.
Frederic C. Bost, M.D., San Francisco, California;
Helen Hagey, M.D., San Francisco, California (by invitation);
Edwin R. Schottstaedt, M.D., San Francisco, California (by invitation).

Report of Results of Treatment of Congenital Dislocation of the Hip Prior to the Age of Eight Years.
C. H. Crego, Jr., M.D., St. Louis, Missouri.

Report of Results of Treatment of Congenital Dislocation of the Hip.
Wallace H. Cole, M.D., St. Paul, Minnesota.

Late End-Result Studies of Treatment of Congenital Dislocation of the Hip.
A. Bruce Gill, M.D., Philadelphia, Pennsylvania.

Follow-up Studies and Additional Observations in Primary Anterior Congenital Dislocation of the Hip.
H. R. McCarroll, M.D., St. Louis, Missouri.

Congenital Dislocation of the Hip with Treatment in Older-Age Group.

Report of Results of Treatment of Congenital Dislocation of the Hip by Osteotomy.
Herman C. Schumm, M.D., Milwaukee, Wisconsin.

Report of Results of Treatment of Unilateral Congenital Dislocation of the Hip by Arthrodesis
Charles J. Frankel, M.D., Charlottesville, Virginia (by invitation).

Report of Results of Treatment of Congenital Dislocation of the Hip by Vitallium-Mold Arthroplasty.
M. N. Smith-Petersen, M.D., Boston, Massachusetts.

Noon: Final Executive Session.

Then follow individual sections on the process in the forearm, the humerus, the clavicle, the tibia, and the femur. A second chapter deals only with extracapsular fractures of the neck of the femur, and the third and last chapter, with intracapsular fractures. There are many illustrations and roentgenographic reproductions, and a complete bibliography at the end of each chapter.

Readers of *The Journal* will find Dr. Soeur's preliminary report on this subject in the April 1946 issue, page 309.

Die Reverdin-Plastik. Dr. Raimund Wittmoser. Vienna, Wilhelm Maudrich, 1946. $7.00.

Perusal of *Die Reverdin-Plastik*, by Dr. Raimund Wittmoser, will disappoint many American readers, because the method emphasized in this exhaustive treatise on skin transplantation has largely been discarded in this country. Sheets of skin, removed with a knife or a dermatome, have been preferred because Reverdin grafts do not provide so firm a surface for bearing weight; they give a mottled appearance to the grafted area; and the donor sites of such grafts are most unsightly. Little mention is made of these cosmetic considerations in the text.

The first section of the book deals with the general topic of skin transplantation from the scientific point of view. This section is illustrated with drawings and photomicrographs. Most of the remainder of the book deals with clinical applications. There are numerous illustrations of lesions in all parts of the body, closed primarily or secondarily with Reverdin grafts. The details of technique are discussed at some length. A final section is concerned with a statistical analysis of the results.

The thoughtful reader of this book will find it very revealing as regards developments in plastic surgery in the past fifteen to twenty years, for the newer techniques of skin transplantation have almost completely outmoded the Reverdin method. The value of this book lies in the discussions of the wound management before and after operation, and in the emphasis on the indications for grafting.

The Medical Annual. A Year Book of Treatment and Practitioner's Index. Editors: Sir Henry Tidy, K.B.E., M.A., M.D. (Oxon.), F.R.C.P., and A. Rendle Short, M.D., B.S., B.Sc., F.R.C.S. Bristol, England, John Wright and Sons Ltd., 1946.

This edition, for the sixty-fourth year that the British Medical Annual has been published, is quite similar to those which have preceded it each year. It consists of 426 pages with forty-six colored plates and numerous figures which amply illustrate the text. Forty-seven of the leading physicians of the British Isles have made contributions to the numerous subjects which appear in the book. The first 386 pages give a review of the year's work in medicine and surgery in England. The remaining pages discuss new preparations and appliances, and new books of the year.

Following its usual policy, the 1946 Medical Annual is most comprehensive in the variety of the subject matter which it contains. Much may be found in its pages of interest to the physician, be ... general practitioner, internist, or surgeon. Due to the excellent general index, the Annual will prove special value as a reference book.

Myasthenia Gravis. Dr. Adelberto R. Goñi. Translated by Georgianna Simmons Gittinger. Baltimc The Williams and Wilkins Company, 1946.

Myasthenia gravis is a disease affecting the voluntary muscles,—principally those concerned w moving the eyes, talking, chewing, and swallowing. In some cases, a similar weakness appears in the nє muscles and in the general body musculature.

The chief symptom is one of easy fatigue with restoration of function after a period of rest. T disease appears to be due to a dysfunction in the transmission of the nerve impulse to the muscle at t synapse. Prostigmine, taken either by mouth or by injection, overcomes the disability in large part, the time being.

The disease is relatively rare; and no systematic account of it has appeared in the literature recent years, until the author's book, originally written in Spanish and published in Buenos Aires, a recently translated into English. Goñi reports in some detail thirteen cases, observed since 1937 Buenos Aires and its vicinity; and reviews the literature of myasthenia gravis, paying particular atte tion to the clinical and pathological aspects of this syndrome. The monograph is thus up to date a contains an extensive list of references to the current literature.

The translation into English is occasionally faulty. The text, nevertheless, gives a good picture the disease.

CORRECTION

Acknowledgment is made of a typographical error in the abstract of an article on The Major Amput tion Stump in Health and Disease, by F. G. St. Clair Strange, which appeared in *The Journal* (28: 8 Oct. 1946). The last clause of the first paragraph should read: "and (4) above the elbow, eight inch from the tip of the *acromion* with the arm at the side".

Instructional Courses, under the chairmanship of Dr. Walter P. Blount, provided a wide choice and were well attended. The Scientific Program was arranged by the Program Committee, of which Dr. Harold B. Boyd was Chairman. This was presented on the afternoon of Monday, January 27, and at the morning and afternoon sessions of Tuesday and Wednesday, and at the morning session on Thursday, January 30, as follows:

MONDAY, JANUARY 27

Afternoon Session

Treatment of Ununited Fractures by Onlay Grafts Without Screw or Tie Fixation.
Dallas B. Phemister, M.D., Chicago, Illinois.

Bone Grafts, an End-Result Study of the Healing Time.
W. A. Bishop, Jr., M.D., Phoenix, Arizona;
Richard C. Stauffer, M.D., Fort Wayne, Indiana;
Captain Alvin L. Swenson, M.C., A. U. S.

A Method Combining a Bone Graft and a Metal Plate in Non-Union of Long Bones.
G. Mosser Taylor, M.D., Los Angeles, California.
Discussion of the foregoing papers:
Surgeon General Norman T. Kirk, M.C., U. S. A.;
George O. Eaton, M.D., Baltimore, Maryland;
Dallas B. Phemister, M.D.

Some Unusual Clinical and Pathological Aspects of Trauma.
C. Fred Ferciot, M.D., Lincoln, Nebraska;
Frank H. Tanner, M.D., Lincoln, Nebraska (by invitation).
Discussion: Edwin F. Hirsch, M.D., Chicago, Illinois (by invitation).

Preliminary Report of the Committee on Prosthetic Devices.
Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Paul E. Klopsteg, Ph.D., Chicago, Illinois (by invitation).

TUESDAY, JANUARY 28

Morning Session

Slipping Epiphysis in the Adolescent Hip.
Paul H. Martin, M.D., Jacksonville, Florida.

Malunited Displaced Upper Femoral Epiphysis. End-Result Study of Sixty-Five Cases Treated by Osteotomy of the Surgical Neck with Internal Fixation.
Carl E. Badgley, M.D., Ann Arbor, Michigan;
John Wolgamot, M.D., Great Falls, Montana;
James Miller, M.D., Seattle, Washington;
Alvin S. Isaacson, M.D., Ann Arbor, Michigan.
Discussion of the foregoing papers:
Lewis Clark Wagner, M.D., New York, N. Y.;
Harold E. Crowe, M.D., Los Angeles, California;
Alan DeForest Smith, M.D., New York, N. Y.;
J. Albert Key, M.D., St. Louis, Missouri;
William T. Green, M.D., Boston, Massachusetts.

Treatment of Congenital Dislocation of the Hip.
Professor Mudr. Bedřich Frejka, Brno, Czechoslovakia (by invitation).

Intertrochanteric Fractures of the Femur: A Survey of Treatment by Traction and Internal Fixation.
Mather Cleveland, M.D., New York, N. Y.;
David M. Bosworth, M.D., New York, N. Y.;
Frederick R. Thompson, M.D., New York, N. Y.
Discussion: Rex L. Diveley, M.D., Kansas City, Missouri;
Paul L. Norton, M.D., Brookline, Massachusetts;
J. Albert Key, M.D., St. Louis, Missouri;
David M. Bosworth, M.D.;
Frederick R. Thompson, M.D.

Principles of Treatment of Multiple Limb Injuries.
Sir Reginald Watson-Jones, F.R.C.S., London, England (by invitation).

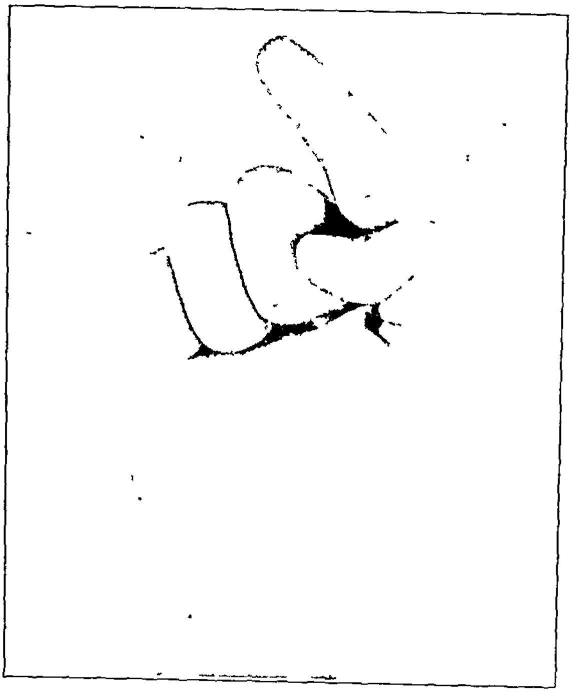

Fig. 1-A

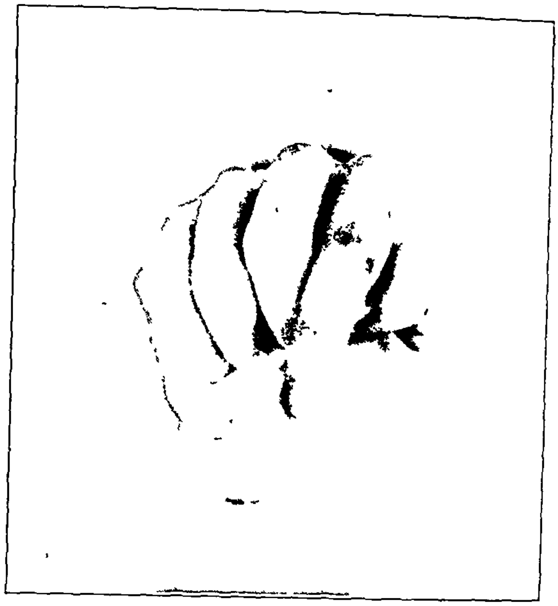

Fig. 1-B

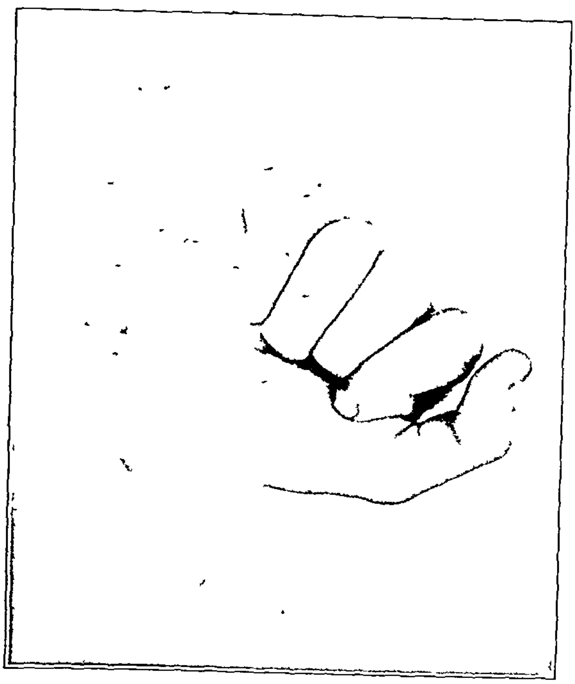

Fig. 1-C

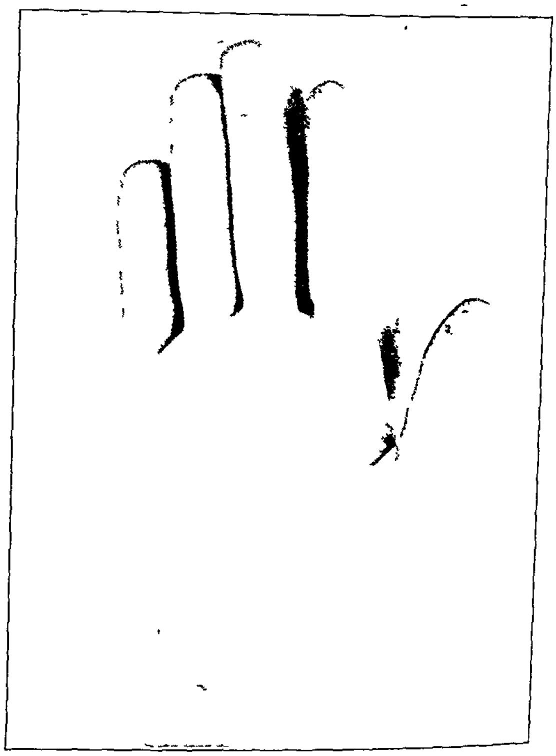

Fig. 1-D

Fig. 1-A: Original photograph of hand in flexion. Patient has loss of flexor tendon to the index finger.
Fig. 1-B: Tendon is stuck in sheath.
Figs. 1-C and 1-D: Range of tendon function after flexor-tendon graft with blocking of median nerve and forceful active freeing of tendon. The palmaris longus was used as a graft.

control of the distal two joints of the finger. There is a tendency for the proximal interphalangeal joint to go into hyperextension, if the sublimis tendon is excised too far distally. This tendency can be controlled by fixing the stump of the sublimis tendon across the proximal interphalangeal joint into the proximal phalanx, with the joint held in about 10 degrees of flexion. It has been suggested by John R. Moore that, in highly specialized personnel, where the laceration is distal to the proximal interphalangeal joint, the sublimis function can be retained and a graft can be extended to the distal phalanx and fixed proximally to the stump of the profundus tendon, thus restoring the intricate mechanism of the finger. This method has proved very satisfactory. It is obvious that a flexor-tendon

Afternoon Session

Treatment of Spondylitis Deformans by Manipulation.
M. S. DeRoy, M.D., Pittsburgh, Pennsylvania;
Harry Fisher, M.D., Pittsburgh, Pennsylvania.
Discussion: Robert W. Johnson, M.D., Baltimore, Maryland;
Dennis S. O'Connor, M.D., New Haven, Connecticut;
Lenox D. Baker, M.D., Durham, North Carolina;
M. S. DeRoy, M.D.

Effect of Antireticular Cytotoxic Serum on the Healing of Fractures. A Preliminary Report of a Clinical Study.
Vernon Thompson, M.D., Los Angeles, California;
Frederic W. Ilfeld, M.D., Los Angeles, California;
John Grube, M.D., Los Angeles, California;
Reuben Straus, M.D., Los Angeles, California;
Moris Horwitz, M.D., Los Angeles, California.
Discussion: Francis M. McKeever, M.D., Los Angeles, California;
Vernon Thompson, M.D.

Veteran's Problem.
Paul B. Magnuson, M.D., Washington, D. C.

Styloidectomy of the Radius in the Surgical Treatment of Non-Union of the Carpal Scaphoid.
Leonard Barnard, M.D., Oakland, California;
Major Sam G. Stubbins, M.C., A. U. S.
Discussion: Ralph Soto-Hall, M.D., San Francisco, California;
Edwin F. Cave, M.D., Boston, Massachusetts;
Leonard Barnard, M.D.

The Contact Splint. Addenda III. Experimental Study of Fracture Sites.
G. W. N. Eggers, M.D., Galveston, Texas;
William H. Ainsworth, M.D., Galveston, Texas (by invitation);
Norman Wright, M.D., Galveston, Texas (by invitation).
Discussion: Arthur G. Davis, M.D., Erie, Pennsylvania;
Harold E. Crowe, M.D., Los Angeles, California;
George J. Garceau, M.D., Indianapolis, Indiana;
G. W. N. Eggers, M.D.

THURSDAY, JANUARY 30

Morning Session

Surgical Experiences with Injury to the Clavicle.
Thomas H. Peterson, M.D., Boston, Massachusetts.
Discussion: E. Bishop Mumford, M.D., Indianapolis, Indiana;
Malcolm B. Hadden, M.D., Berkeley, California (by invitation).

Fusion of the Hip in Children—Chandler Method.
Charles N. Pease, M.D., Chicago, Illinois.

Tuberculosis of the Hip in Children.
H. Relton McCarroll, M.D., St. Louis, Missouri;
Robert D. Heath, M.D., St. Louis, Missouri.
Discussion: Robert Perlman, M.D., Cincinnati, Ohio;
H. D. Morris, M.D., New Orleans, Louisiana;
Joseph S. Barr, M.D., Boston, Massachusetts;
A. Bruce Gill, M.D., Philadelphia, Pennsylvania;
Gerald Gill, M.D., Oakland, California;
Charles N. Pease, M.D.;
H. Relton McCarroll, M.D.

Flexor Tendon Grafts to the Fingers and Thumb.
Walter C. Graham, M.D., Santa Barbara, California.

Tendinous Reconstruction of the Hand Following Irreparable Peripheral Nerve and Brachial Plexus Injury.
Captain C. A. Luckey, M.C., A. U. S. (by invitation);
Captain S. R. McPherson, M.C., A. U. S. (by invitation).

Fig. 3-A

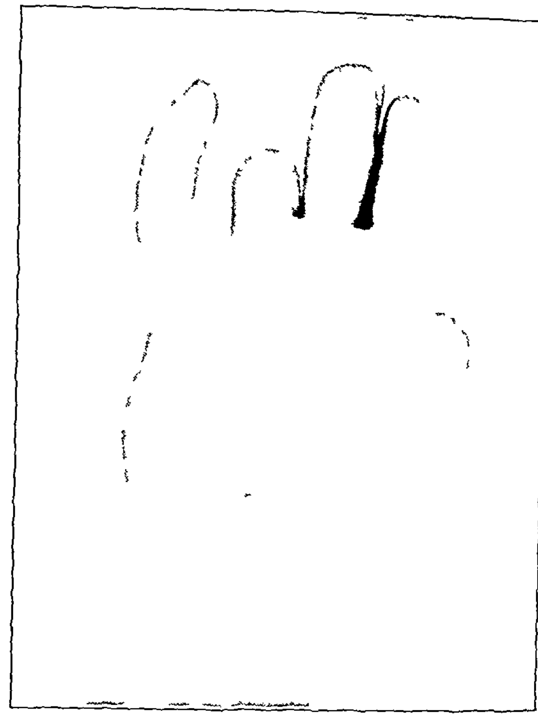

Fig. 3-B

Fig. 3-A: Shows loss of portion of fingers and thumb and of the flexor tendon to the little finger Because parts of each of the other digits had been destroyed, the graft was applied to the little finger.
Fig. 3-B: Photograph shows extension possible after operation.

Fig. 3-C
Amount of flexion is shown.

for grafts. These tendons are usually not so desirable, because they have a tendency to fray. The peronaeus longus or the tendon of the plantaris muscle may be used, but one must bear in mind that a tendon which is too large will become necrotic in the center and produce more local reaction. In addition, it has a tendency to adhere to the sheath. Occasionally a tendon from another individual has been used, and has proved satisfactory.

The site of suturing a tendon graft is extremely important. The suture line should never be between the proximal interphalangeal crease and the distal palmar crease. Distally, the graft may be sutured to the stump of the profundus tendon or into the distal phalanx at the original insertion of the profundus tendon. Proximally, the suture line should be located in the base of the palm or above the wrist.

The *procedure of flexor-tendon grafting first includes excision of scar* tissue and of the stump of the old tendon. In many cases, flaps are required to replace badly scarred areas. The distal and proximal stumps of the lacerated tendon are freed with a tendon stripper. It is desirable to excise the distal portion of the stump and to thread the graft through the pulleys, thus eliminating the tendency for a few tendons to become bowstrung. We have had better success when the graft is fixed distally by the Bunnell technique with pull-out wire. Attempts to thread sutures back and forth through a short stump distally have proved unsatisfactory. Proximally, either the Bunnell technique with pull-out wire may be used, or an end-to-end suturing with silk may be done. The silk technique, as described by Bunnell, has proved satisfactory, the suture line being wrapped with the sheath of the lumbricalis. In a flexor-tendon graft to the thumb, the graft is fixed distally with a pull-out wire, and the proximal suture line is well above the wrist. If there is extreme scarring

William M. Krigsten, M.D., Sioux City, Iowa
Donovan L. McCain, M.D., St. Paul, Minnesota
Leo James McDermott, M.D., Portland, Maine
Frederick M. Marek, M.D., New York, N. Y.
George Miyakawa, M.D., Charleston, West Virginia
Manley A. Page, M.D., Chicago, Illinois
Karl F. Pelka, M.D., Los Angeles, California
John F. Register, M.D., Greensboro, North Carolina
Fred C. Reynolds, M.D., St. Louis, Missouri
Richard C. Ritter, M.D., Pittsburgh, Pennsylvania
Peter G. Shifrin, M.D., Detroit, Michigan
Chester Shinbach, M.D., Columbus, Ohio
Michael Skovron, M.D., Erie, Pennsylvania
Frank E. Stinchfield, M.D., New York, N. Y.
Fred Louis Stutle, M.D., Peoria, Illinois
Alvyn Weiss Tramer, M.D., Cleveland, Ohio
Vernon C. Turner, M.D., Evanston, Illinois
Margaret Watkins, M.D., Dallas, Texas
I. Mark Zeligs, M.D., Cincinnati, Ohio

It was announced that the following were elected to Corresponding Membership on October 5, 1946:

Robert Merle D'Aubigne, M.D., Paris, France
Jacques Leveuf, M.D., Paris, France
Arnoldo Periera Rodo, M.D., Lisbon, Portugal
E. J. Kanan, M.D., Porto Alegre, Brazil

The following candidates were elected to Corresponding Membership on January 25, 1947:

Alexander Gillies, M.D., Wellington, New Zealand
Guillermo De Velasco Polo, M.D., Mexico City, Mexico
Alejandro Velasco Zimbron, M.D., Mexico City, Mexico

The following candidates were elected to Honorary Membership on January 25, 1947:

José Luis Bado, M.D., Montevideo, Uruguay
Professor Mudr. Bedřich Frejka, Brno, Czechoslovakia
Sir Reginald Watson-Jones, F.R.C.S., London, England

The following members were transferred to Emeritus Membership on January 25, 1947:

Roland Hammond, M.D., Providence, Rhode Island
Charles A. Reed, M.D., Minneapolis, Minnesota
Loring Swaim, M.D., Boston, Massachusetts

The officers of The Academy for 1947 are:

President: Rex L. Diveley, M.D., Kansas City, Missouri
President-Elect: Myron O. Henry, M.D., Minneapolis, Minnesota
Vice-President: Alan DeForest Smith, M.D., New York, N. Y.
Secretary: Harold B. Boyd, M.D., Memphis, Tennessee
Treasurer: Fremont A. Chandler, M.D., Chicago, Illinois
Librarian-Historian: Edward L. Compere, M.D., Chicago, Illinois

The Fifteenth Annual Convention will be held at the Palmer House, January 24–29, 1948, under the presidency of Dr. Rex L. Diveley.

PATHOLOGICAL DIAGNOSTIC SERVICE

The American Academy of Orthopaedic Surgeons by yearly appropriation finances the Registry of Orthopaedic Pathology, a constituent member of the American Registry of Pathology. The Registry is in operation at the Army Medical Museum at present, but will soon be housed in the Institute of Pathology.

The Registry offers full, prompt diagnostic service by skilled men who are particularly interested in skeletal pathology on all lesions of bones, joints, and muscles, including tumors. It also holds cases in its files for follow-up in a very efficient manner.

Prepared specimens, gross or microscopic, should be sent by local pathologist or laboratory to: Registry of Orthopaedic Pathology, Army Medical Museum, 7th Street and Independence Avenue, S.W., Washington 25, D. C. If possible, an abstract of the case history and the roentgenograms should accompany the slides or tissue. Quick diagnosis is afforded if properly prepared material is sent.

Surgeons are urged to avail themselves of this service offered by the Academy. There is no charge.

Robert W. Johnson, Jr., M.D.
Chairman of the Committee

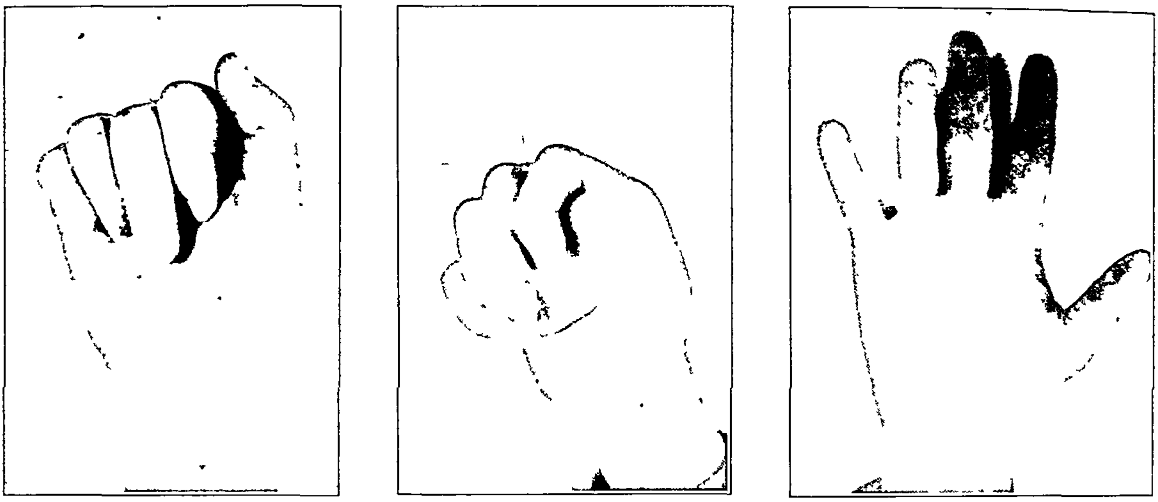

Fig. 6-A Fig. 6-B Fig. 6-C

Fig. 6-A: Original photograph of hand in flexion, after loss of profundus tendon to middle finger, the sublimis tendon being intact.
Figs. 6-B and 6-C: Show flexion and extension after flexor-tendon graft to restore profundus action.

marked atrophy or damage to their natural muscles. This muscle switching can be carried out as indicated, without jeopardizing the function of the finger. A period of muscle exercises and training prior to the tendon-grafting is very desirable and helpful, when the laceration is of long standing, and may eliminate the necessity of switching a muscle.

The most important part of flexor-tendon grafting comes after the surgery has been ompleted. It is our policy to splint the hand and wrist for a period of twenty-one days; following that, the splinting is removed and moderate active motion and full passive motion are instituted, care being taken not to extend the fingers fully. After four weeks, moderate resistive exercises are instituted; and in six weeks, flexion against resistance is encouraged. The technique of freeing the flexor-tendon graft in its newly formed sheath is extremely important. Each joint should be held individually, and forceful active flexion should be encouraged. Forceful extension is also necessary to prevent fixed flexion contractures. This should not be done in less than six weeks, as there is danger of tearing the distal attachment of the tendon. In practically all instances, a snap will be felt as the tendon is freed in the sheath; and an increase in the flexion function will be noted

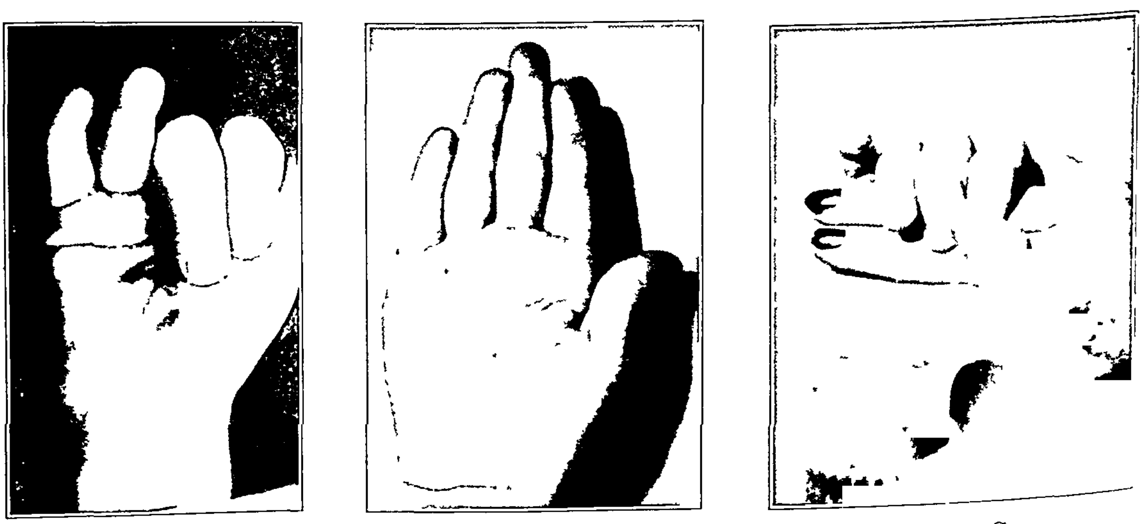

Fig. 7-A Fig. 7-B Fig. 7-C

Fig. 7-A: Original photograph of hand in flexion shows lacerated flexor tendon to the ring finger and middle finger in a child of six years.
Figs. 7-B and 7-C: Show function six months after tendolysis of previously sutured tendon to little finger and flexor-tendon graft to ring finger.

Surgical Treatment of the Soft Tissues. Edited by Frederic W. Bancroft, A.B., M.D., F.A.C.S., and George H. Humphreys, II, A.B., M.D., Sc.D., F.A.C.S. Philadelphia, J. B. Lippincott Co., 1946. $15.00.

Surgical Treatment of the Soft Tissues is another in the series on Surgical Treatment, issued under the editorship of Frederic W. Bancroft, M.D. The Associate Editor of this volume is George H. Humphreys, II, M.D., Valentine Mott Professor of Surgery, Columbia University, College of Physicians and Surgeons, and Director of Surgical Service, The Presbyterian Hospital, New York.

The book is divided into twenty-one sections, written by different authors, and each section has its own bibliography. Of special interest to readers of *The Journal* are the sections dealing with Tendon Injuries of the Hand, Infections of the Hand, and Plastic Surgery.

One chapter is devoted to sulfonamide therapy and the use of penicillin in surgical practice.

The volume is well planned, the illustrations are excellent, and the actual printing is a distinct credit to the publishers. This is a valuable addition to the series.

Introduction to Surgery. Virginia Kneeland Frantz, M.D., and Harold Dortic Harvey, M.D. New York, Oxford University Press, 1946. $2.50.

It is welcome to see the basic principles of surgery emphasized, as they are in this little book, which has been written as a text for the teaching of surgery to the second-year class of the College of Physicians and Surgeons at Columbia University, where the authors are Assistant Professors of Surgery.

The book deals almost entirely with the reactions of the various tissues of the body to varying forms of trauma. In many instances, the fundamental approach to treatment is discussed. The book is well written, concise, and accurate. The last chapter deals with history-taking and the physical examination.

A short bibliography is appended. Were these references introduced into the text, there might be more incentive for consulting them, but this is minor criticism.

Dr. Whipple's foreword is an excellent exposition of the necessity for the student learning to differentiate between fact and theory, and for the development of his critical faculties.

Certainly, as an introduction to the understanding of surgery, it is a valuable work for the student, and instructors in surgery would do well to consult it for its exposition of what should be taught.

A Manual of Tomography. M. Weinbren, B.Sc. (S.A.), M.R.C.S. (Eng.), L.R.C.P. (Lond.), F.F.R. (Lond.), D.M.R.E. (Camb.). London, H. K. Lewis and Company, Ltd., 1946. 45 shillings.

The Manual covers a series of lectures delivered by the author, a well-known radiologist in South Africa. The book is well printed and contains numerous excellent illustrations. A large number of cases are presented. Weinbren is enthusiastic about the tomographic method of roentgenography (laminagraphy, body section, and so forth), and stresses its diagnostic value.

The reviewer agrees that tomography is valuable in that it occasionally demonstrates a lesion in the skeletal system and chest that cannot be shown by any other method, and that, with it, certain processes are more readily visualized than with other techniques. The majority of pathological conditions, however, can be demonstrated by variations of the usual technical procedures, with less radiation to the patient and to the technician. With the present trend toward increasing use of radio-active materials, caution against excess radiation in any form is urged.

Accidentes vasculares de los miembros (Vascular Damage to the Extremities). Ed. 2. F. Martorell. Barcelona and Buenos Aires, Salvat Editores, S. A., 1946.

This book is the second edition of one by the same name by Dr. Martorell, who is Chief of the Section of Vascular Surgery at the *Instituto Policlínico* in Barcelona. It is a presentation of various vascular disorders, which represent a branch of medicine which is becoming more and more important to the surgeon and to the internist.

The book is divided into three parts: The first deals with arterial damage to the extremities, the second with damage to the veins, and the third with damage to the lymphatic vessels of the extremities.

Treatment of the various conditions is discussed, as well as the distinctive signposts which aid in diagnosing the varieties of damage which may occur. Many case histories are presented with excellent photographs, which should be of great interest to the reader. To facilitate rapid comprehension of the clinical cases which are cited, there are numerous diagrammatic sketches, and at the end of each chapter is a bibliography of important works in the field under discussion.

L'ostéosynthèse au clou (Osteosynthesis by Pinning). R. Soeur. Paris, Masson et C^{ie}, 1946. 325 francs.

This book represents a personal report of many cases of intramedullary pinning performed by the author over a period of several years. The favorable, as well as the unfavorable, aspects of the method are presented, and of equal interest to the orthopaedic surgeon is the discussion of the technique itself and of the indications for its use. Three methods of osteosynthesis by pinning are discussed as they apply to diaphyseal fractures and to the femur.

The actual plan of the book is a useful one. In an introductory chapter, Dr. Soeur discusses the general background of pinning,—its history, the choice of material and instruments used, the importance of proper reduction and accurate roentgenographic control, and, finally, arguments for and against pinning.

TENDINOUS RECONSTRUCTION OF THE HAND FOLLOWING IRREPARABLE INJURY TO THE PERIPHERAL NERVES AND BRACHIAL PLEXUS *

BY MAJOR C. A. LUCKEY AND CAPTAIN S. R. MCPHERSON

Medical Corps, Army of the United States

Wounds incurred in combat have produced a variety of nerve lesions in the upper extremity. Besides injuries at various levels to the radial nerve, the median nerve, and the ulnar nerve, combined involvement of the median and ulnar nerves was also common. Injuries to the brachial plexus, either complete or partial, were produced frequently. In addition to these involvements of the main trunk, many cases were seen of damage to the nerves to one or several muscles of the forearm and hand. Frequently, normally functioning hands were seen with paralysis of only one muscle, — for example, the extensor pollicis longus, the flexor pollicis longus, the first dorsal interosseus, or the flexor digitorum profundus tendon of the index finger.

This paper deals only with the reconstruction of motor function in irreparable nerve injuries. In addition to those cases in which the nerve or nerves could not be sutured, it also includes cases in which the nerves were sutured, but function returned only partially or not at all.

Before tendon transplantation can be carried out, several conditions must exist.

1. *The joints to be activated should be limber.* Stiff joints are conducive to failure of the procedure.

2. *A satisfactory muscle and tendon should be available for transplantation.* In some cases of extensive paralysis, one may have to use a tendon, the muscle of which had been paralyzed but has recovered. If recovery is only partial, excellent results should not be anticipated. However, sometimes there is no choice and one has to use an incompletely recovered muscle. When there is a choice of muscles, that one should be used whose tendon has a range of excursion which most nearly equals that of the dysfunctioning tendon.

3. *Scar tissue in the path of the transplant should be excised.* If scar tissue is always excised before transplantation, the insertion of tubes to form tendon sheaths for the transplanted tendons is seldom necessary. One cannot transplant a tendon through scar tissue and expect gliding of that tendon.

Light adhesions will form along the tendon whether or not mesothelial-lined channels have been formed beforehand, since these small fibrous strands carry small blood vessels and are instrumental in revascularization of the tendon. These adhesions must either be broken down or elongated, or both, by active use of the tendon after healing has taken place.

The early work done by Biesalski and Mayer has served as a stimulus to tendon surgery. Their work on the anatomy and physiology of tendons, together with the surgical techniques they fostered, has been responsible, to a great extent, for the progress made in the field of tendon surgery.

RESTORATION OF FUNCTION TO AN INDIVIDUAL MUSCLE

Loss of function due to damage of an individual muscle can frequently be restored, since usually there will be a choice of muscles to use.

On several occasions, the first dorsal interosseus has been the only muscle paralyzed by a wound through the palm. Its action can be restored readily by transplanting the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1947.

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FLEXOR-TENDON GRAFTS TO THE FINGER AND THUMB *

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The loss of the flexor tendon to a finger or thumb handicaps greatly the function of the hand. When the flexor tendons have been cut, there is loss of both the pinch and hook mechanisms of the fingers, as well as of the ability to grasp and to hold objects. It is obvious that the most logical treatment is a restoration of the flexor-tendon function to the finger or thumb. When a flexor tendon has been cut for some time, the proximal end will retract into the palm of the hand, so that it is impossible to do an end-to-end anastomosis. Any excess scar through which the tendon glides will inhibit function of the tendon, unless it is completely excised and replaced by healthy, viable tissue. There is no reason to attempt to restore flexor-tendon function to a finger which has no sensation, because there is a tendency for the patient to substitute a finger with normal sensation in preference to using the one which has been grafted. To restore function to a finger requires a tremendous effort on the part of the patient, and he must use the finger to recover the tendon action. The following views relating to this problem are based upon experiences gained in 141 flexor-tendon grafts. The methods advocated have been found to yield gratifying results in suitable cases.

A great deal of work to produce tendon sheaths has been done by Mayer, Thatcher, and Ransohoff, by inserting various materials through the fingers to produce a gliding surface for the tendon. We have not attempted this method, as we felt that Nature would restore a sheath, if a moving tendon could be produced. It is our feeling that the pulleys are extremely important to prevent bowstringing of the tendon, and that the graft should be threaded through. A pulley should not be cut to form a sheath for the tendon. It is also extremely important that the tendon should not pass over exposed bone, as it would certainly adhere. A grafted tendon should have considerable freedom in the sheath, as there is appreciable swelling of the graft during the healing stage, and a tight sheath would tend to strangle the graft and produce necrosis and adhesions.

Not all fingers with lacerated tendons are amenable to grafting. The primary consideration should be given to sensation. In addition, there is no hope of restoring flexor-tendon function to a finger that is excessively scarred. It is preferable to do an arthrodesis at the distal interphalangeal joint, and a tendon graft only as far as the middle joint. The little finger is the most difficult in which to restore flexor-tendon function with a graft. Few people realize that this finger is used very little in the ordinary function of the hand, with the exception of operating a machine, such as a typewriter, or playing a musical instrument. In patients whose occupations require the use of such instruments, a graft is indicated. As a rule, the sublimis tendon is excised and the profundus tendon assumes the

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FIG. 2-A

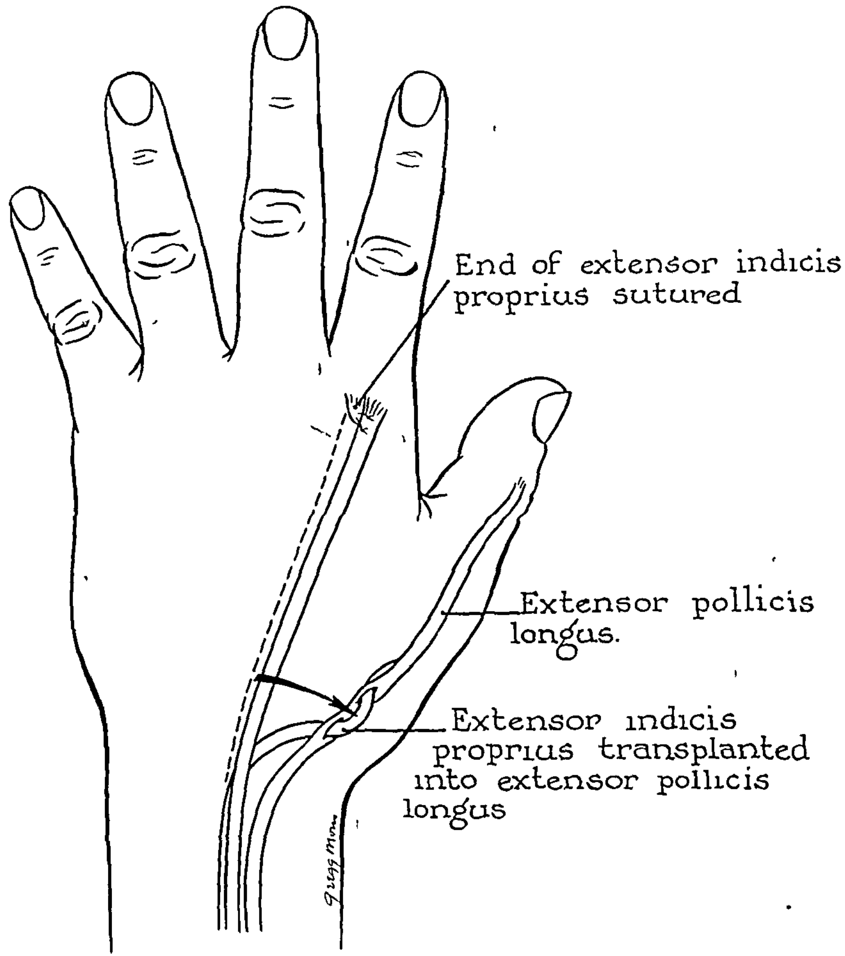

FIG. 2-B

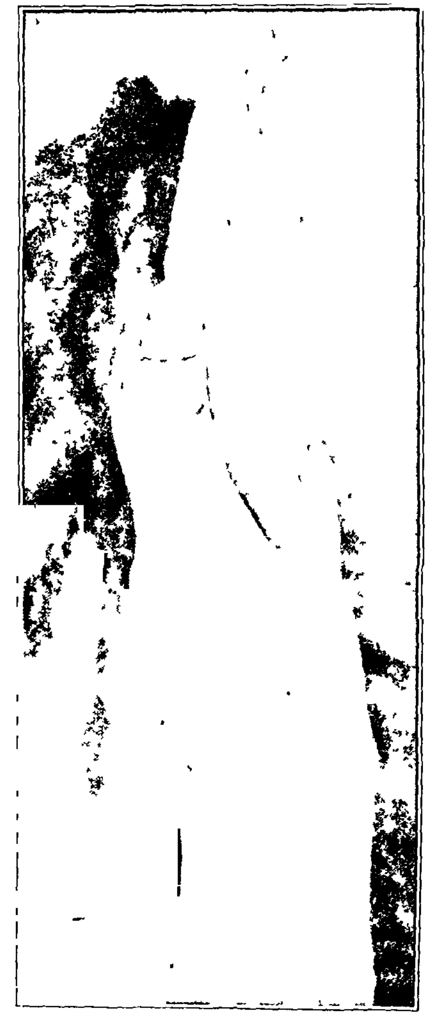

FIG. 2-C

Fig. 2-A: Preoperative photograph shows limitation of extension of thumb.
Fig. 2-B: Commonly accepted procedure in paralysis of extensor pollicis longus. Extensor indicis proprius is transplanted into extensor pollicis longus.
Fig. 2-C: After operation, thumb can be extended.

graft should not be attempted on a finger which has any stiffness of the joints. The finger joints should move as freely as those of a normal finger before a graft is attempted. An effort should also be made to restore the muscle tone, as it is extremely important that sufficient motor power be present to mobilize the tendon through the sheath.

There are many donor sites from which one may secure a graft. The most accessible is the tendon of the palmaris longus, when present. This tendon should be dissected out so that the gliding surface surrounding the tendon will also be transplanted, as mobilization will thus be made simpler. If both the sublimis and profundus tendons have been lacerated, the sublimis tendon may be used as a graft. It is wise to fix the proximal stump of the sublimis into the profundus tendon, thus giving added motor power to the finger. The long extensor tendons of the second, third, fourth, and fifth toes are also available

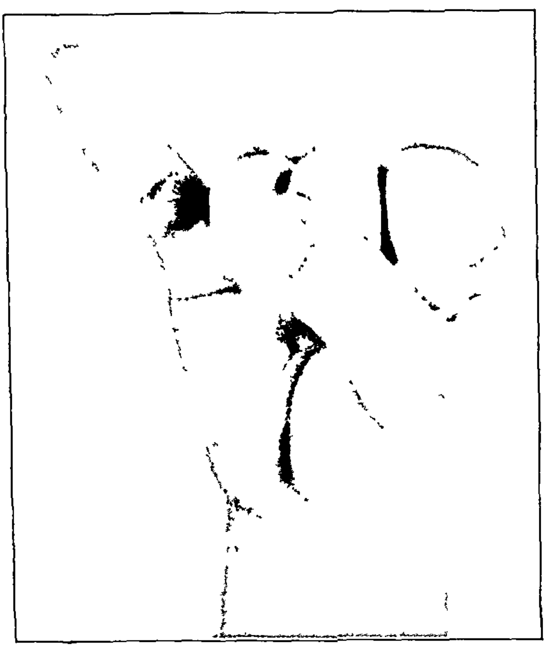

FIG. 2-A

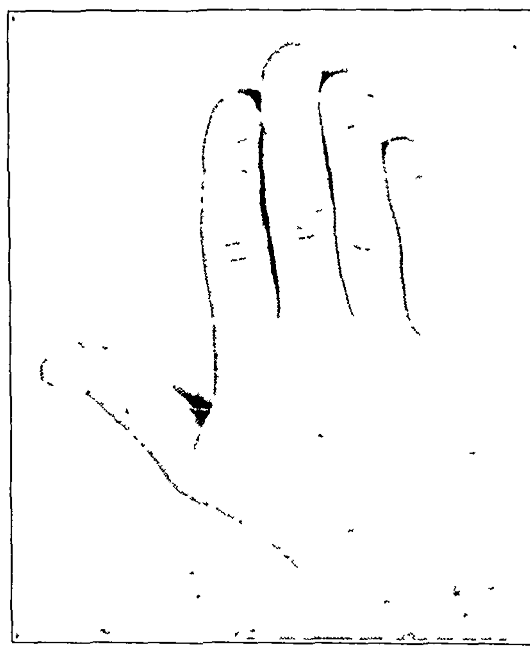

FIG. 2-B

Fig. 2-A: Loss of flexor tendon to little finger is shown.
Fig. 2-B: Shows extension of hand after treatment by flexor-tendon graft.

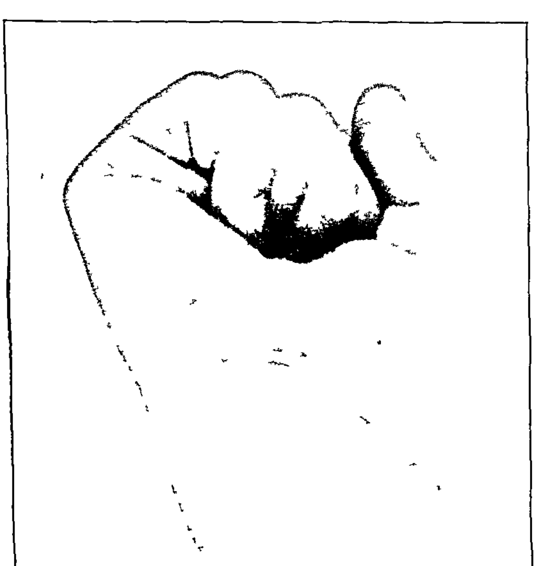

FIG. 2-C

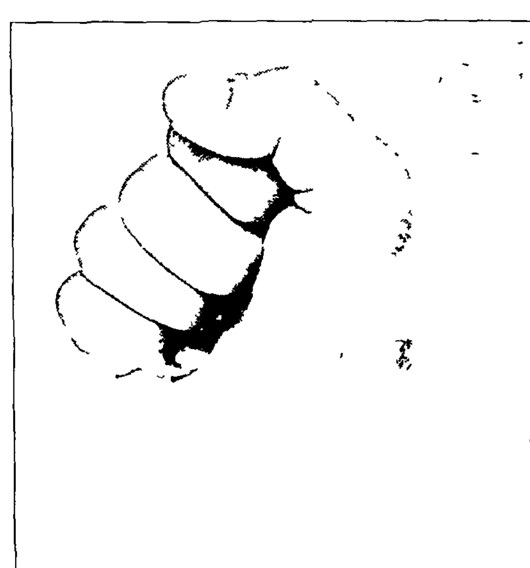

FIG. 2-D

Photographs show postoperative function.

serving the oblique pull around Lister's tubercle, this can be accomplished. The distal phalanx usually can be extended weakly by the extensor pollicis brevis. The extensor indicis proprius has a greater range of excursion than the wrist extensors; therefore, the authors prefer the extensor indicis proprius when doing the transplantation. The tension of these transplants must be watched closely. If they are too lax, they do not restore the desired action. If they are too snug, the thumb can be

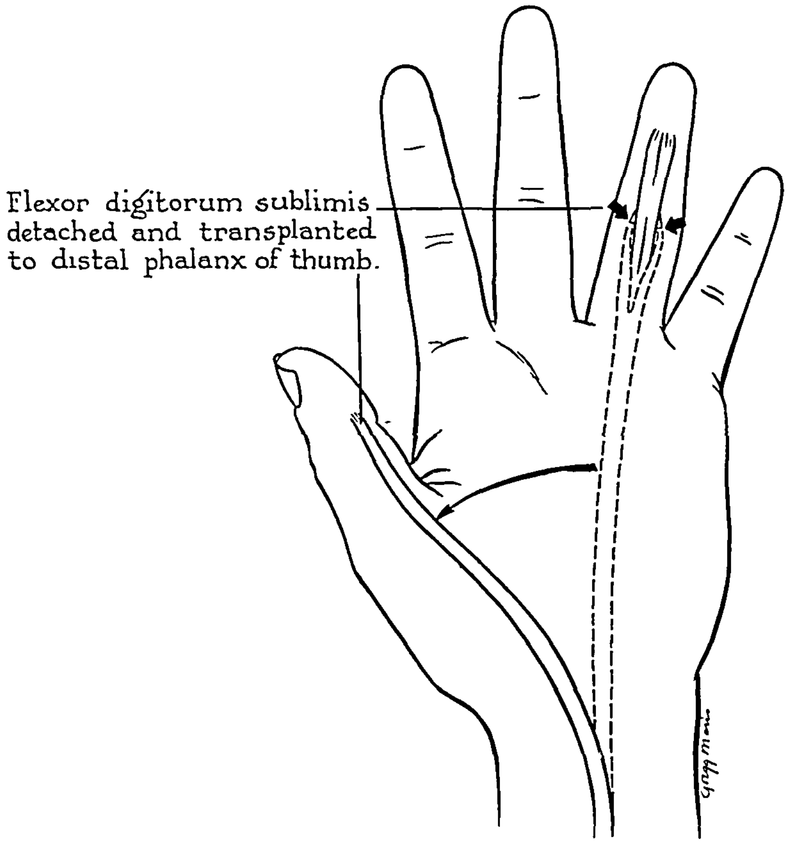

FIG. 4-A

Fig. 4-A: For destruction of flexor pollicis longus and its tendons, the flexor digitorum sublimis of the ring finger is detached from its insertion and transplanted to the distal phalanx of the thumb This procedure gives complete range of flexor activity of the thumb. If the ring finger does not have a good flexor profundus and sublimis, one of the procedures to be described subsequently should be employed. If the flexor pollicis longus tendon is intact, the transplantation should be done at wrist level.

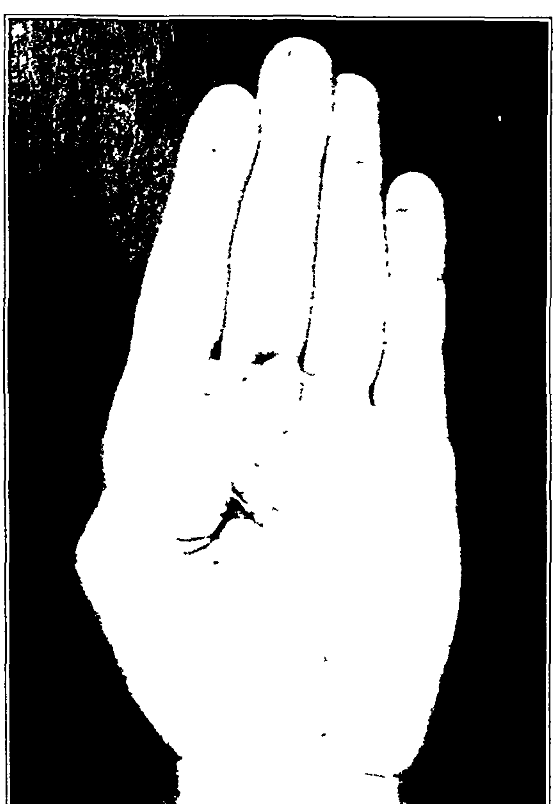

FIG. 4-B

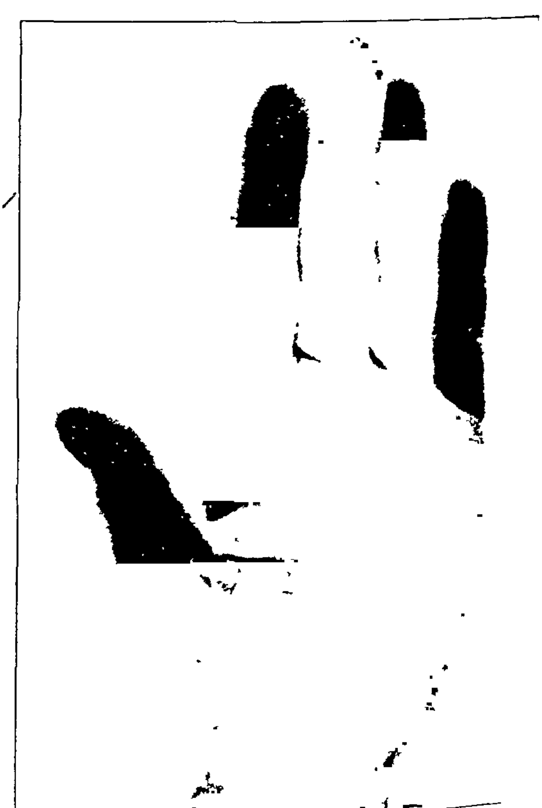

FIG. 4-C

Fig. 4-B: Postoperative photograph, showing range of flexion of thumb.
Fig. 4-C: Showing complete extension of thumb, after operative procedure described in Fig. 4-A.

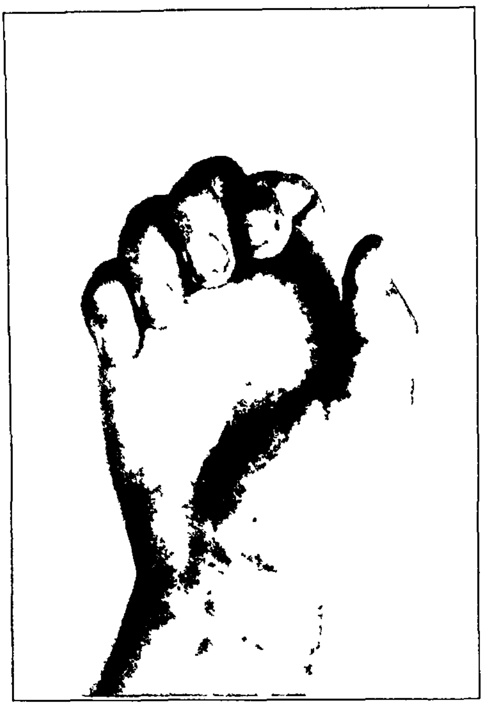
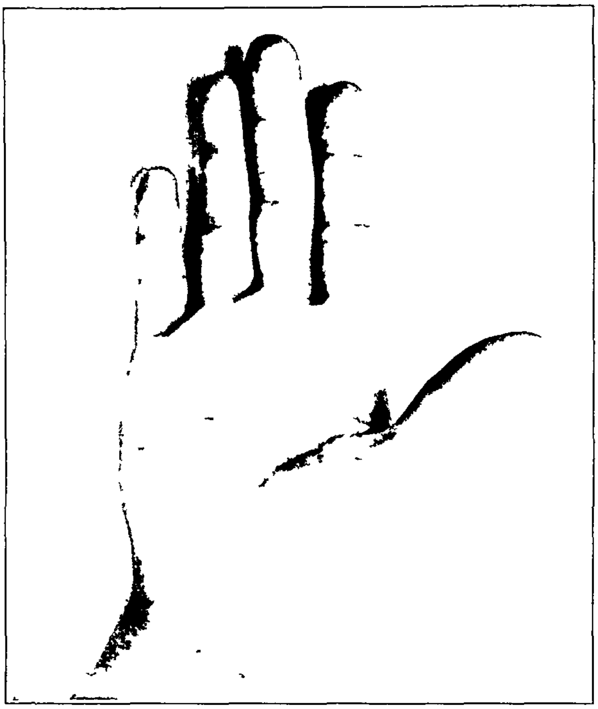

FIG. 4-A FIG. 4-B

Flexor tendon of thumb has been lacerated through the thenar eminence. Photographs show function of the tendon following flexor-tendon graft

in the base of the palm, threading of the tendon outside of the carpal canal may be done.

On many occasions, it is desirable to substitute a muscle from another finger for the motor power. This is particularly true in lacerations of long standing, when advanced atrophy of the muscle is secondary to the laceration. The sublimis tendon of the ring finger may be used as motor power for the index finger, middle finger, or thumb, when there is

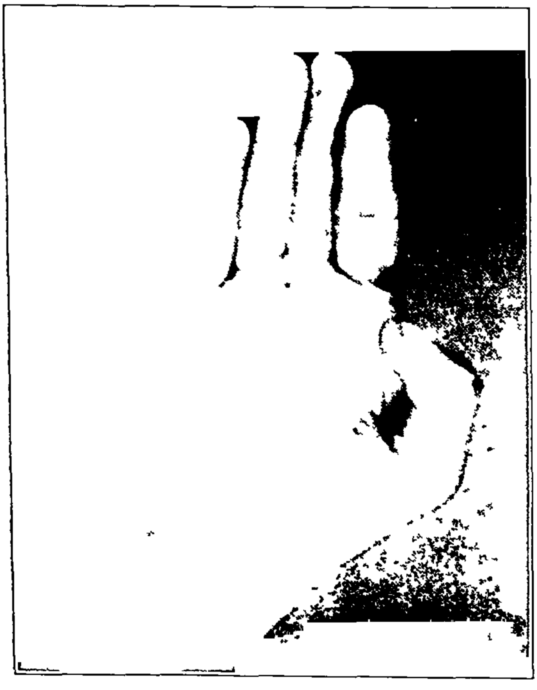
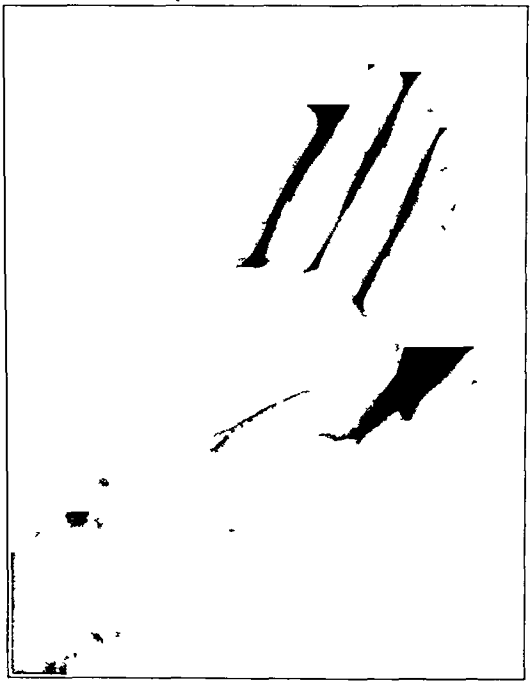

FIG. 5-A FIG. 5-B

The flexor tendon of the thumb has been completely lacerated, with marked scarring Final photographs reveal function (The flexor tendon has been transplanted subcutaneously to avoid scarred areas)

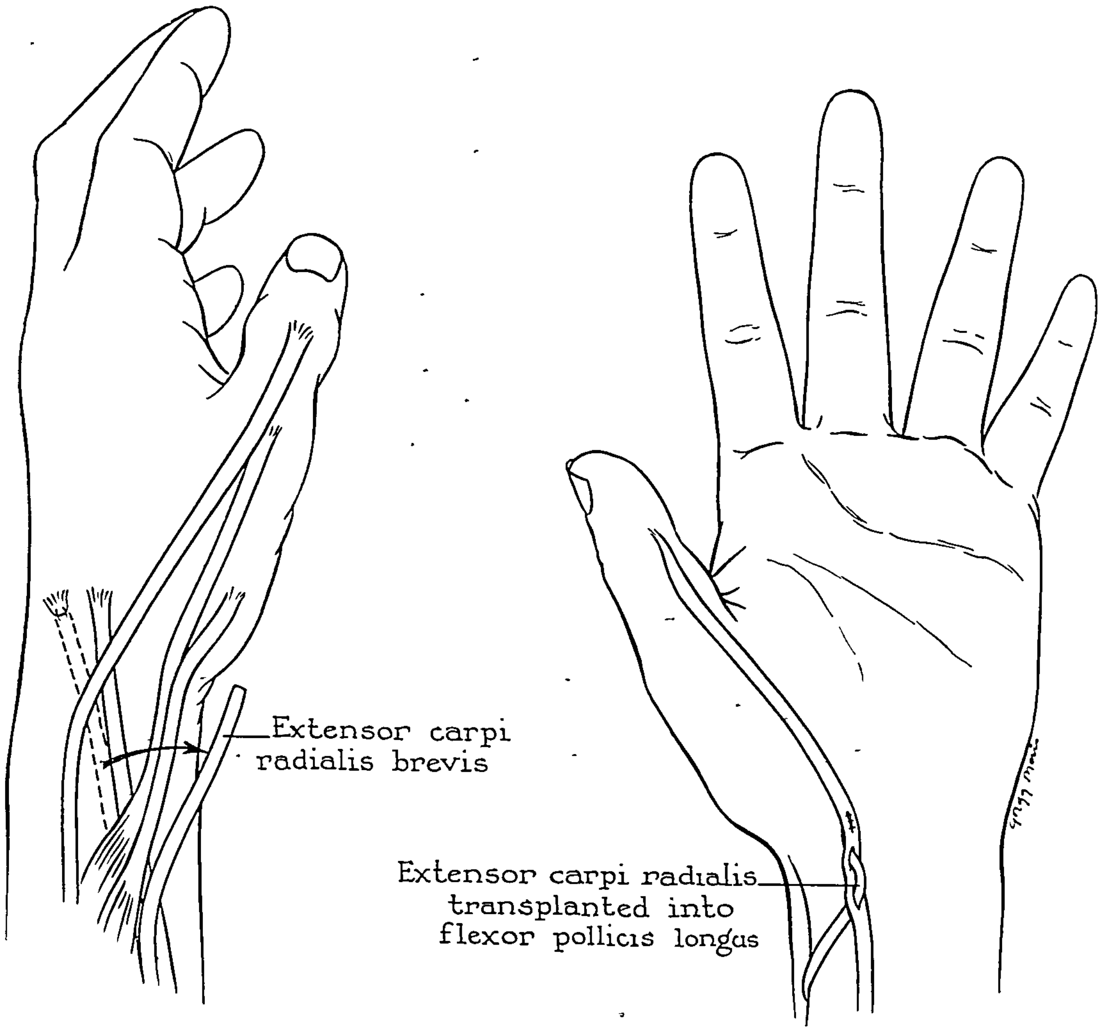

FIG. 6-A

For paralysis of the flexor pollicis longus, the extensor carpi radialis brevis is transplanted into the flexor pollicis longus. Good results are obtained when extensors are transplanted into flexors, because of their synergistic action.

lifted satisfactorily, but it cannot be brought across the palm well.

Loss of action of the abductor pollicis longus and the extensor pollicis brevis brings the thumb next to the metacarpal of the index finger. This close relationship between the thumb and the index finger interferes with the grasping of objects [6]. Transplantation of the extensor carpi radialis brevis into the tendons of these two muscles produces excellent results. If one of the radial extensors of the wrist is not available, the palmaris longus can be used, as is done routinely in transplantation for radial-nerve paralysis. Tension on these transplants will seldom, if ever, be excessive. As a rule, we should attempt to transplant extensors to flexors and flexors to extensors [14]. However, when this is not possible, flexors can be transplanted into flexors and extensors into extensors, with good results.

The flexor pollicis longus is sometimes the only muscle paralyzed. Direct trauma may also destroy the tendon of this muscle. Suture of a high median-nerve lesion frequently will bring about a return of function in the long finger flexors and wrist flexors, and a return of sensation. Return of intrinsic-muscle function is usually negligible, or not present at all. In addition, flexor pollicis longus action in many instances is minimum, even when the maximum time has elapsed after nerve suture. If only the flexor pollicis longus is paralyzed, a number of possibilities exist for restoration of its function. In view of the long range of excursion of this tendon, a tendon and a muscle of equal excursion should be used, whenever possible.

The only tendons with excursion sufficient to carry the thumb through a full range of motion are the flexor digitorum sublimis and the flexor digitorum profundus tendons;

immediately. If the function of a graft has not been restored in eight weeks, the prognosis is discouraging.

Operative tendolysis by stripping the tendon after six or seven weeks frequently will restore considerably more function. The operative incision should be above the wrist, and the tendolysis should be carried out with a tendon stripper so that immediate active mobilization of the fingers can be instituted. On occasions, the distal attachment of a flexor graft will pull loose, and it is our feeling that a re-grafting should be done immediately. The results from immediate re-grafting have been extremely gratifying, and this procedure should be considered on all occasions in which the graft pulls loose, either distally or proximally. Frequently a patient will be reluctant to put sufficient flexor pull on a tendon to free the adhesions along the sheath, because of pain in the hand. We have found it quite helpful to block the median or the ulnar nerve and to promote flexion in the anaesthetized finger. Often a graft which is not functioning will be restored to almost 90 per cent. of function by this simple procedure. Hand blocks, as described by Bunnell, are used continuously after the fourth week. It is our feeling that occupational therapy is extremely helpful in restoring flexor-tendon function, and we have encouraged this type of mobilization of a tendon.

CONCLUSIONS

1. In a severely scarred finger, fusion of the distal interphalangeal joint is frequently preferable to an attempt to restore flexor-tendon function. If the finger has good sensation and good joint function, a flexor-tendon graft will restore useful function.
2. The graft should be dissected out, to retain the gliding material on the tendon.
3. The restoration of function requires constant effort on the part of the operator in the form of encouragement and personal supervision of the mobilization of the tendon.

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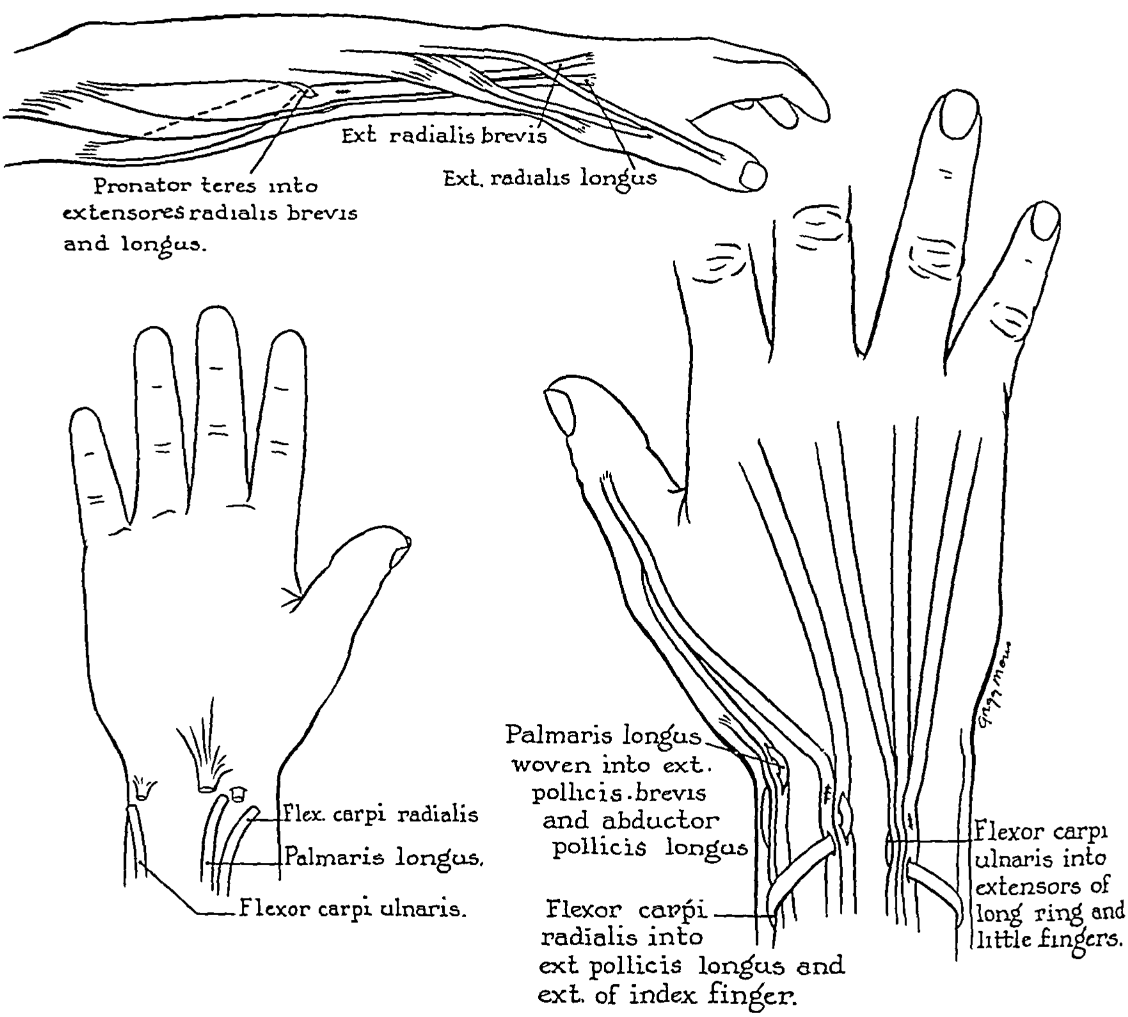

FIG. 7-A

Procedure used for correcting irreparable paralysis of radial nerve:
1. Flexor carpi radialis is transplanted into extensor pollicis longus and extensor of index finger.
2. Flexor carpi ulnaris is transplanted into extensor tendons of long finger, ring finger, and little finger.
3. Palmaris longus is transplanted into abductor pollicis longus and extensor pollicis brevis.
4. Pronator teres is transplanted into extensor carpi radialis longus and extensor carpi radialis brevis.
The transplanted flexor tendons, as shown, extend too acutely. Their line of pull is considerably straighter than shown here.

FIG. 7-B

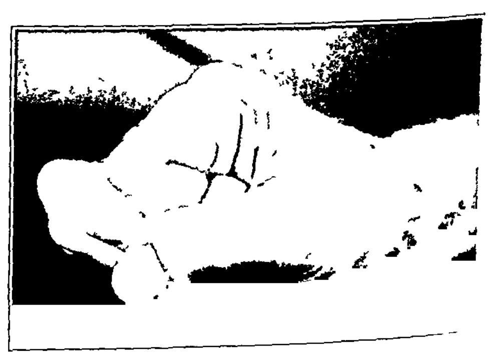

FIG. 7-C

Show extension and flexion possible after operative procedure described in Fig. 7-A.

the dysfunctioning tendon to the adjacent functioning profundus tendon, or by utilizing an adjacent active sublimis tendon, as recommended by Stiles and Forrester-Brown.

RADIAL-NERVE PARALYSIS

Tendinous reconstruction for permanent paralysis of the radial nerve gives good results. The authors have used the method advocated by Sir Robert Jones, with slight

extensor indicis proprius into the tendinous expansion of the first dorsal interosseus (Figs. 1-A, 1-B, and 1-C). This procedure is also used by Bunnell[5] to restore abduction of the index finger in irreparable paralysis of the ulnar nerve.

The action of the extensor pollicis longus is restored by transplanting the extensor indicis proprius[6] or the extensor carpi radialis brevis (or the extensor carpi radialis longus) into the extensor pollicis longus tendon (Figs. 2-A, 2-B, 2-C, 3-A, 3-B, and 3-C). If the extensor pollicis longus is only paralyzed and no damage has been done to its tendon, the extensor carpi radialis transplant should be proximal to the wrist. This preserves the oblique pull around Lister's tubercle. In restoration of function to the extensor pollicis longus, one must strive to get the thumb and its metacarpal extended actively in the plane of the palm. With the proper tension and by pre-

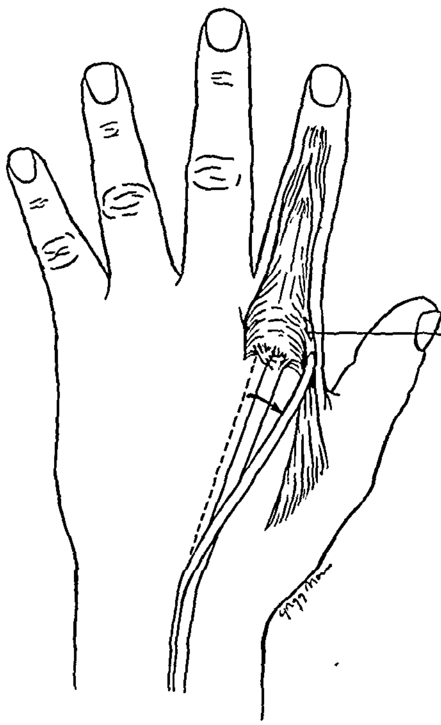

FIG. 1-A

Procedure devised by Bunnell for paralysis of first dorsal interosseus. Extensor indicis proprius is transplanted into tendon of first dorsal interosseus.

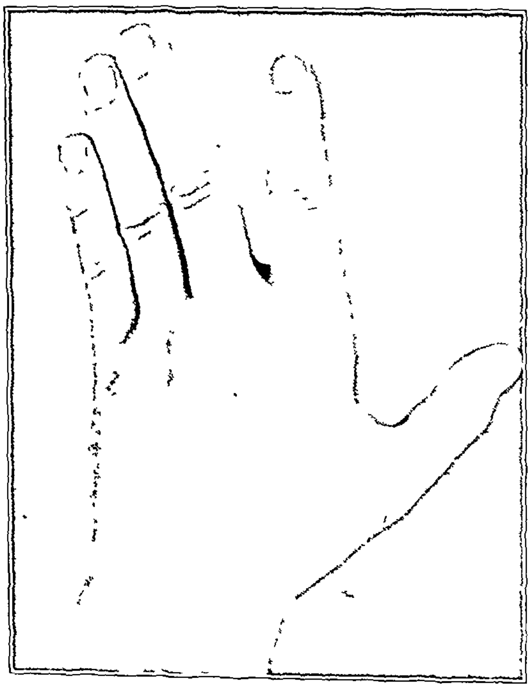

FIG. 1-B

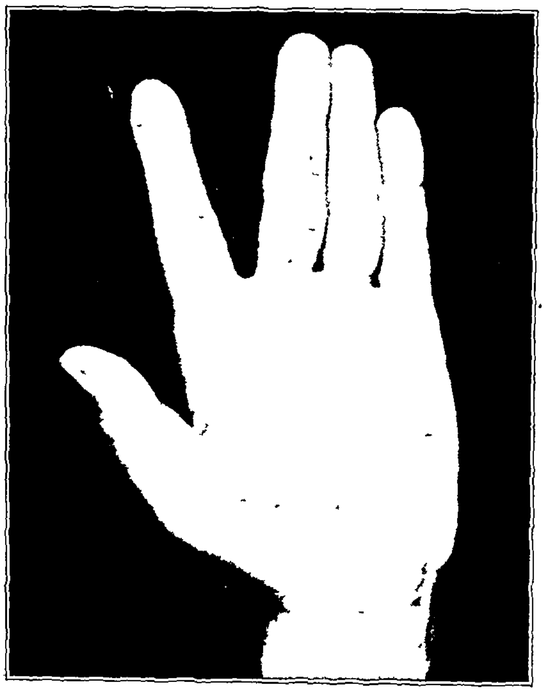

FIG. 1-C

Fig. 1-B: Preoperative photograph shows adduction of long finger, ring finger, and little finger, but no abduction of index finger.

Fig. 1-C: *Photograph taken after operation shows abduction of index finger.*

No function was obtained from the transplant. After shortening of the already transplanted tendon was carried out by the authors, the patient obtained excellent results. Some surgeons advocate wrist fusion for radial-nerve paralysis. There is some instability of the wrist as the result of transplanting all the wrist flexors [13, 15]. Arthrodesis can be

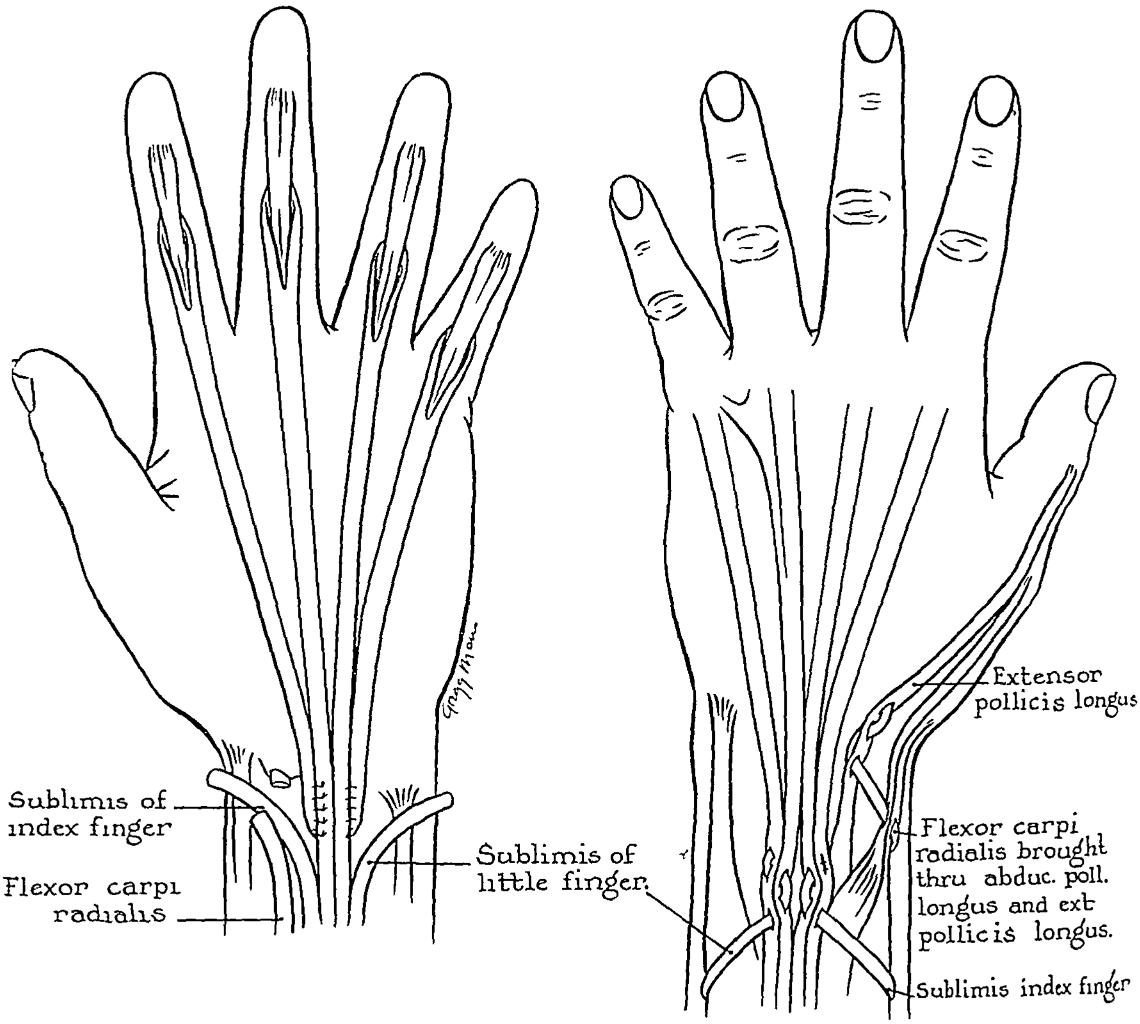

FIG. 9-A

Another procedure used in correction of irreparable paralysis of the radial nerve is the following:

1. Sublimis of little finger and of index finger severed at wrist; proximal end of distal segment is sutured to adjacent sublimis tendons.
2. Sublimis of little finger transplanted to extensors of little finger and ring finger.
3. Sublimis of index finger transplanted to extensors of index finger and long finger.
4. Flexor carpi radialis transplanted to extensor pollicis longus and extensor pollicis brevis, and to abductor pollicis longus.

This procedure is not advocated, because the sublimis tendons are too short to be transplanted posteriorly.

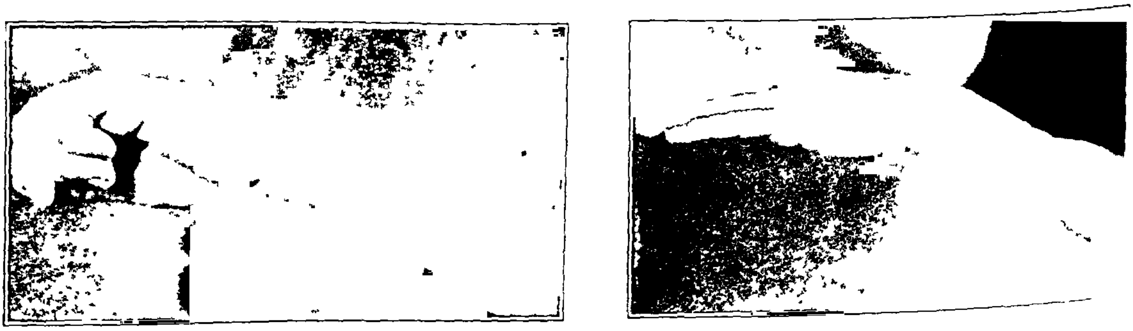

FIG. 9-B FIG. 9-C

Show flexion and extension obtained after operative procedure described in Fig. 9-A. Extension is not sufficient.

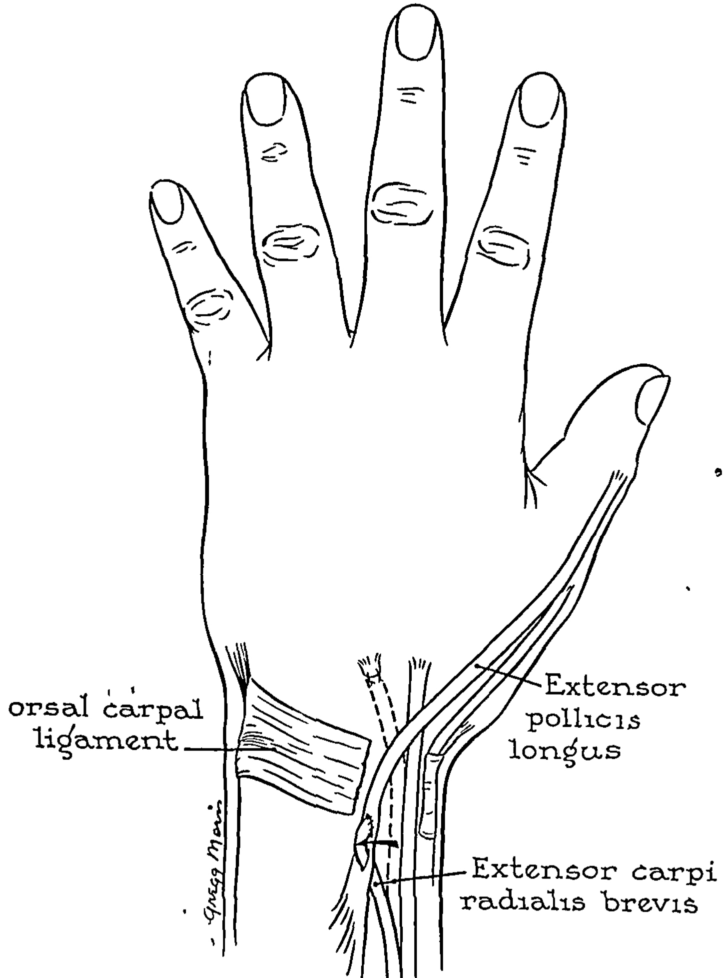

FIG. 3-A

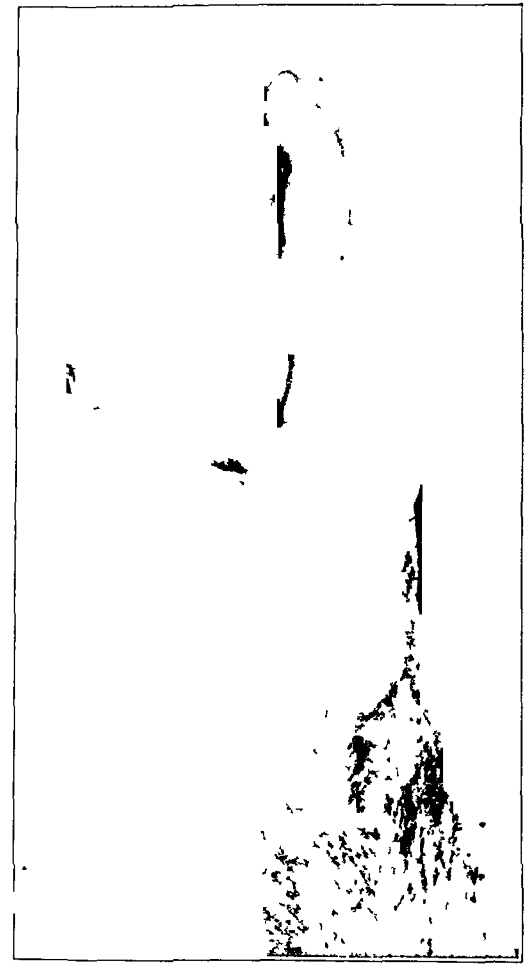

FIG. 3-B

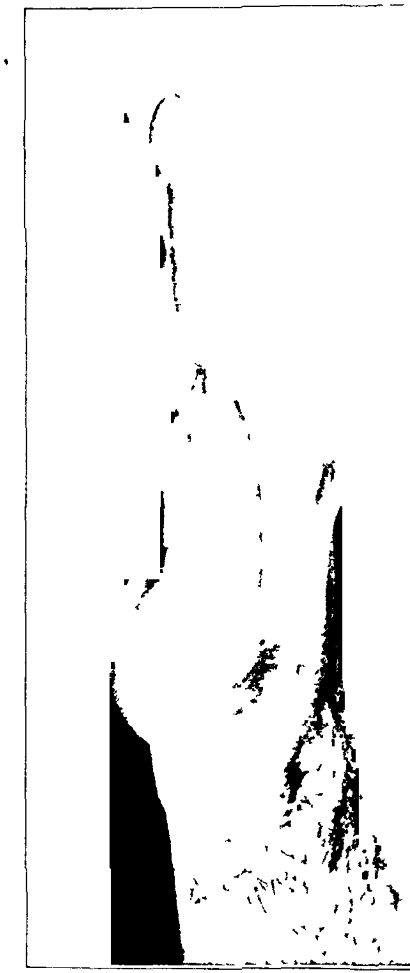

FIG. 3-C

Fig. 3-A: When the extensor carpi radialis brevis is used to restore activity of the extensor pollicis longus, the transplantation should be done proximal to the dorsal carpal ligament, if possible. This retains the oblique pull around Lister's tubercle.

Figs. 3-B and 3-C: Postoperative photographs show range of motion of the thumb.

extensor indicis proprius, as shown in Figure 1-A. A similar procedure is used to restore abduction of the little finger by utilization of the extensor digiti quinti [5].

The area of absolute anaesthesia in ulnar-nerve paralysis is limited to the little finger. Whether or not the anaesthetic little finger should be excised depends largely upon the occupation of the patient. If he works with machinery, or if he is subject to temperatures which might produce burns, the finger should be amputated. The decision should be made by the patient.

Transplantation of the sublimis to overcome clawing of the fingers, due to intrinsic-muscle loss, has been carried out in thirteen cases at Letterman General Hospital. Improvement in the clawing occurs invariably, and usually the improvement is quite pronounced. Flexion may be limited for a short while, but it soon returns. One must remember that only a small proportion of individuals with intrinsic-muscle damage have enough clawing to warrant surgery.

MEDIAN-NERVE PARALYSIS

In lesions of the median nerve in the distal part of the forearm, the chief disability, in addition to the sensory loss, is the loss of ability to oppose the thumb. Numerous methods for restoration of opposition of the thumb have been described. In 1921, Ney suggested transplanting the proximal end of the tendon of the extensor pollicis brevis subcutaneously across the thenar eminence and suturing it to the palmaris longus, but pulling deep to the transverse carpal ligament. Bunnell [4] subsequently transplanted the tendon volar to the transverse carpal ligament, and pulled from the direction of the pisiform. In addition, to utilize the motion at the metacarpophalangeal joint, Bunnell suggested that the tendon have its effective pull from the base of the proximal phalanx rather than from the metacarpal head. The sublimis tendon has also been used to restore opposition [12]. One advantage of this procedure is that there is no tendon suture along the gliding portion of the tendon The chief difficulty in restoring the function of opposition to hands which have been injured in war is in mobilizing the metacarpal of the thumb. Many of the patients have

FIG. 12-A

Shows clawing due to ulnar-nerve paralysis, before operation.

FIG. 12-B

FIG. 12-C

Show flexion and extension possible after sublimis tendons of the little finger and the ring finger have been transplanted to their respective extensor mechanisms, as shown in Fig 11-A.

Fig. 5-A

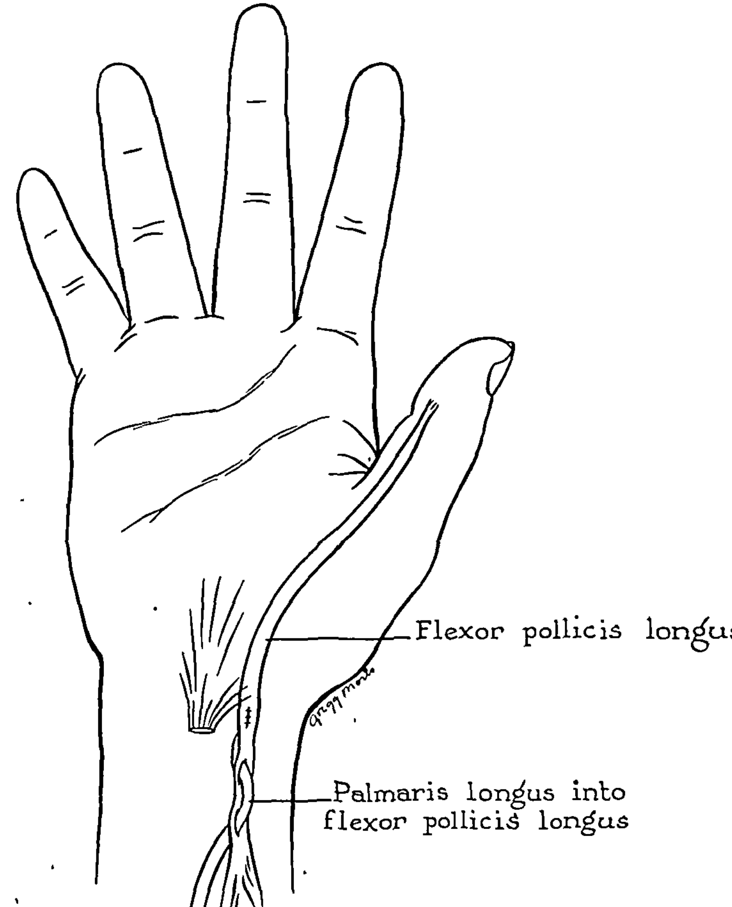

Fig. 5-B

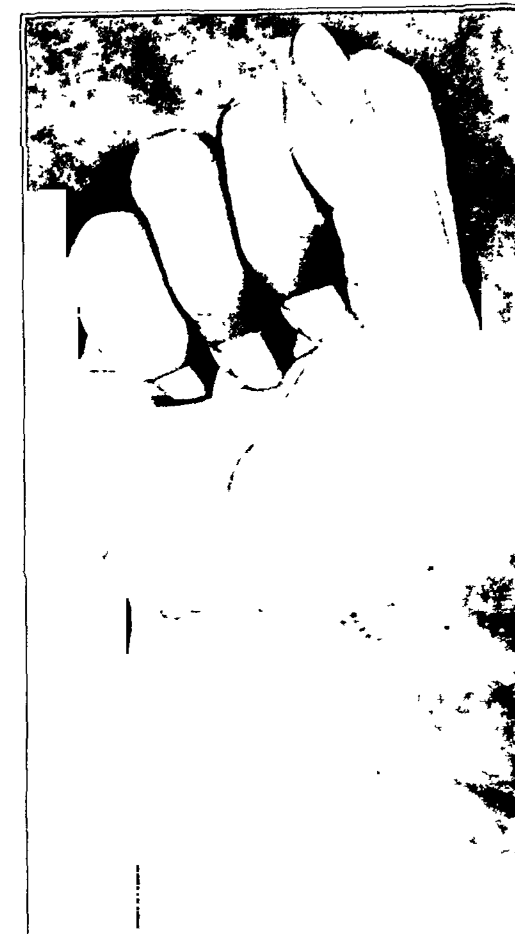

Fig. 5-C

Fig. 5-A: Preoperative photograph of hand with paralysis of flexor pollicis longus.

Fig. 5-B: *Procedure for correcting paralysis of flexor pollicis longus.* The palmaris longus is transplanted into the tendon of the flexor pollicis longus. In median-nerve paralysis with incomplete recovery (poor return, or none, in the flexor pollicis longus), this procedure can be used, or the flexor carpi radialis, if functioning normally, can be used as a transplant.

Fig. 5-C: Shows hand after procedure described in Fig. 5-B has been carried out. Flexion of the thumb is not complete, due to limited range of palmaris longus.

finger flexors (Figs. 15-A, 15-B, and 15-C). (The range of excursion of the brachioradialis has been found to be 1.5 centimeters.)

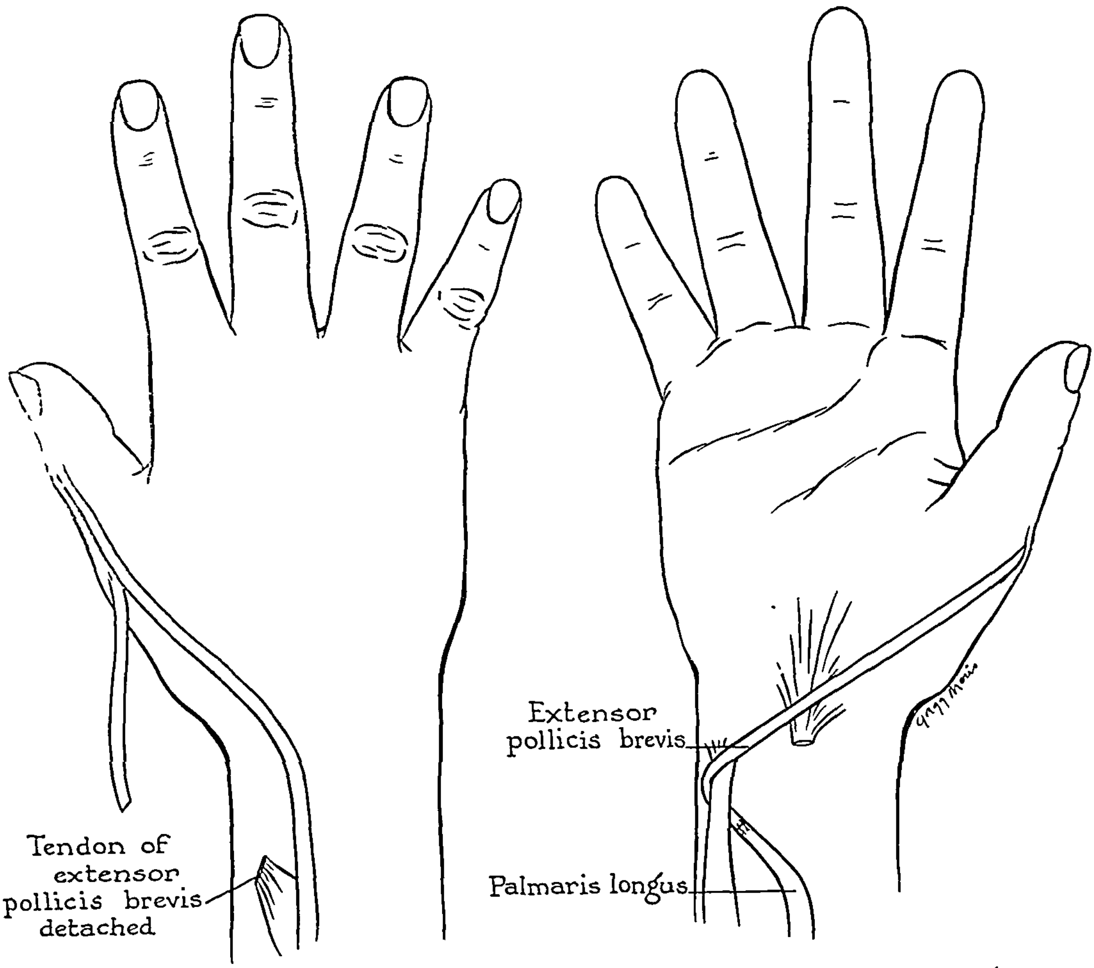

Fig. 14-A

Bunnell procedure for correction of paralysis of opponens pollicis is carried out as follows:
1. Tendon of extensor pollicis brevis is detached proximally, transplanted subcutaneously across thenar eminence, and looped around tendon of flexor carpi ulnaris.
2. Palmaris longus is detached at insertion and sutured to transplanted tendon of extensor pollicis brevis.

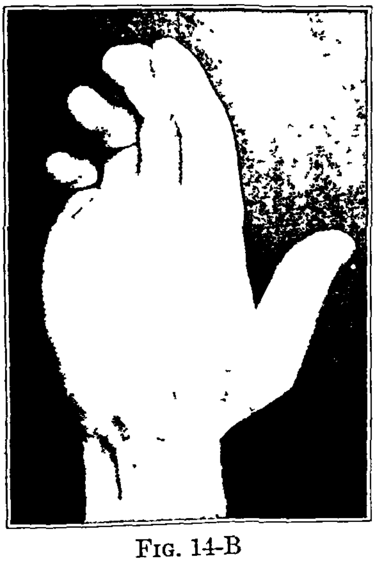

Fig. 14-B

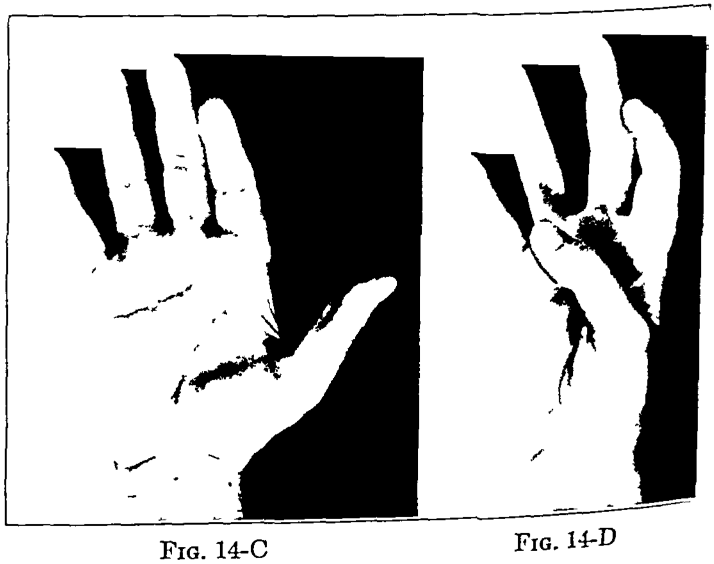

Fig. 14-C

Fig. 14-D

Fig. 14-B: Shows clawing of long finger, ring finger, and little finger, before operation.
Figs. 14-C and 14-D: Postoperative photographs show extension and opposition achieved by procedure described in Fig. 14-A.

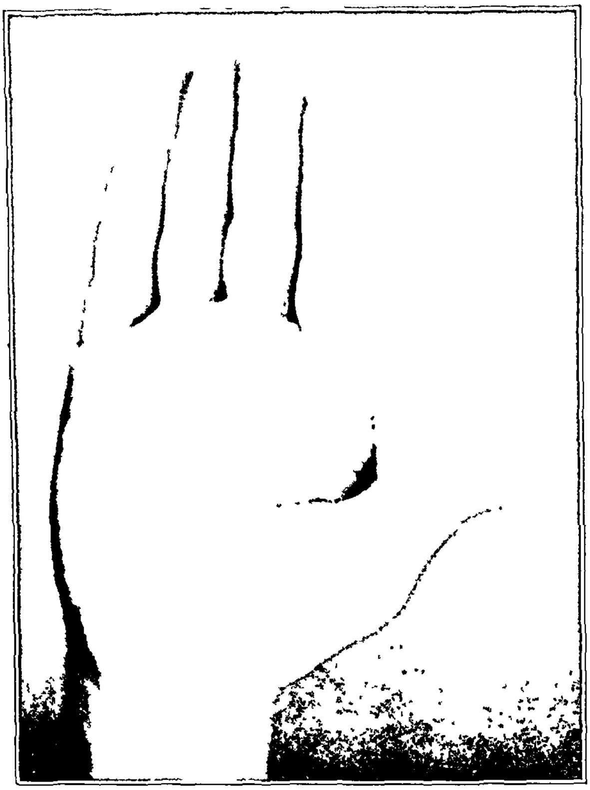

Fig. 6-B

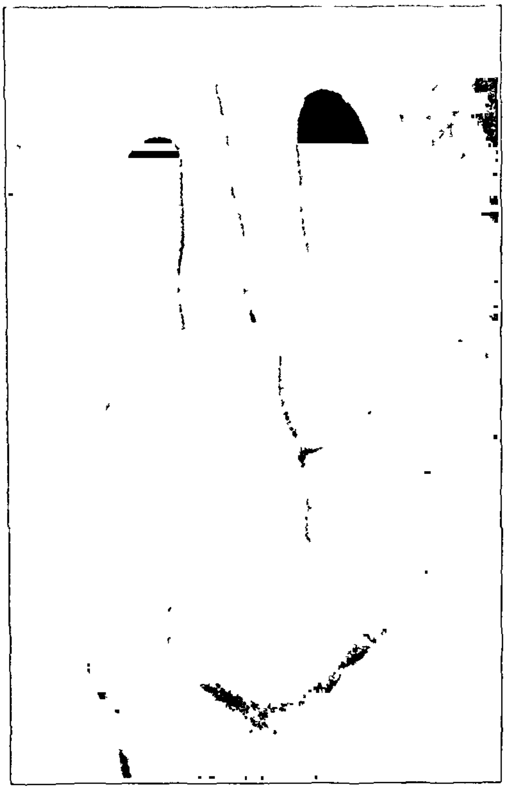

Fig. 6-C

Fig. 6-B: Shows hand before operation.

Fig. 6-C: Amount of flexion possible after operative procedure described in Fig. 6-A has been carried out.

but the flexor digitorum profundus tendons should not be sacrificed. If the tendon of the flexor pollicis longus is also damaged, the procedure shown in Figure 4-A should be employed. If the flexor pollicis longus tendon is intact, and only the muscle is paralyzed, the flexor digitorum sublimis of the ring finger should be detached proximal to the flexor tunnel; and the proximal end of the distal segment should be sutured to the flexor digitorum sublimis of the long finger. The distal end of the proximal segment should then be transplanted to the flexor pollicis longus. This restores full flexion of the thumb. If the flexor digitorum sublimis tendons are functioning poorly, as the result of a median-nerve injury with only partial recovery, or if the flexor digitorum profundus of the finger under consideration is not working well, some other tendon should be used.

The palmaris longus (Fig. 5-B), the flexor carpi radialis, the wrist extensors, or the brachioradialis may be used, but their range of excursion is less than that of the flexor pollicis longus. According to Bunnell, the wrist tendons have a range of approximately one and one-quarter inches, while the flexor pollicis longus has a range of about two and one-quarter inches. Full flexion of the thumb is not regained in these cases; therefore, the thumb should be in slight flexion when the tendon is sutured. There will be some limitation of thumb extension if the transplantation is done with the thumb in slight flexion; however, it is more important to obtain adequate active flexion of the thumb than full extension.

The extensor carpi radialis longus or the extensor carpi radialis brevis can be used most advantageously, because of their synergistic action with the flexors [14]. Here the transplanted tendon should also be sutured with the thumb in slight flexion, since the range of excursion of the wrist extensors is no greater than that of the wrist flexors (Fig. 6-A). In cases in which the radiocarpal joint has been arthrodesed, the wrist flexors and extensors are more suitable for transplantation, since all the motion then is in the joint of the thumb and none is taken up by a mobile wrist.

Loss of individual action of the flexor digitorum profundus can be restored by suturing

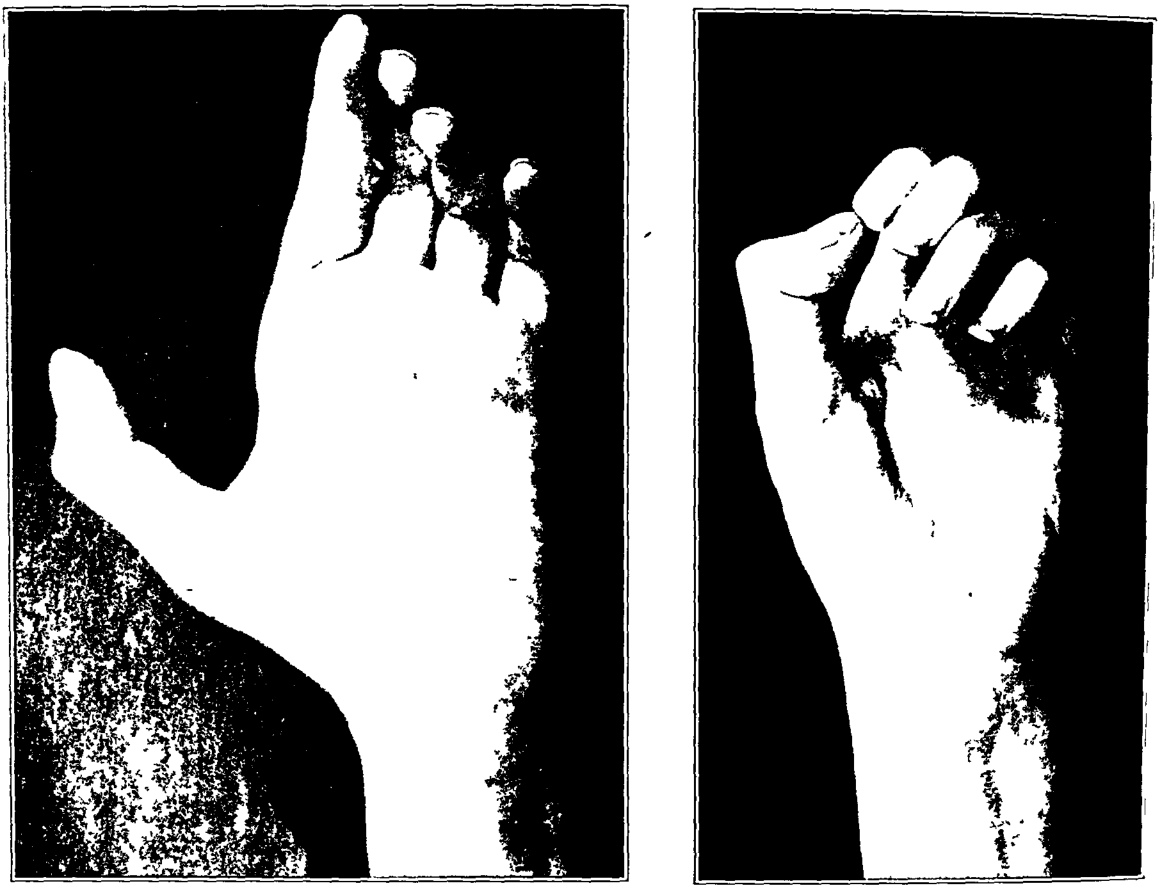

FIG. 15-B FIG. 15-C

Show extension and flexion possible after operation by procedure described in Fig 15-A.

FIG. 16

Fig. 16: Bone block of thumb metacarpal to maintain position of opposition. This procedure should be used when the thumb metacarpal is not sufficiently mobile, when suitable muscle and tendon are not available to restore active opposition, or when these conditions coexist.

metacarpal did not become sufficiently mobile to justify a tendon transplantation; so a bone block was done (Fig. 16) The bone block seems to be indicated in some cases of Volkmann's ischaemia with extensive fibrosis of the muscles, especially if the forearm muscles are also badly damaged, thus prohibiting a successful transplantation. Considerably more difficulty is involved in obtaining satisfactory function of the hand when there is ischaemic necrosis and fibrosis of the muscles, in addition to paralysis of the median and ulnar nerves, than when the nerves are damaged and extensive fibrosis of the muscles does not exist. Clawing of the fingers is an inevitable sequela in these individuals, due to the absence of intrinsic-muscle function. If clawing becomes extensive, the interphalangeal joints which are responsible for most of the deformity can be fused in partial flexion. We have never carried out this procedure in this group, but it is a

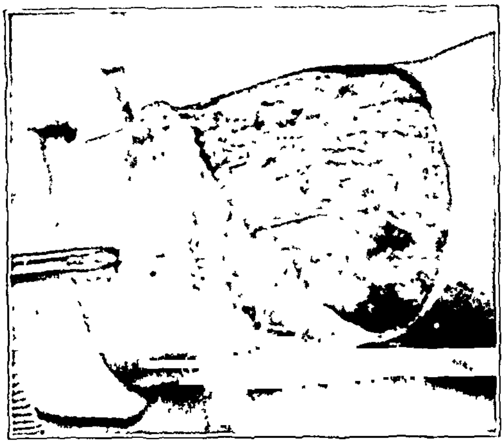

FIG. 8-A

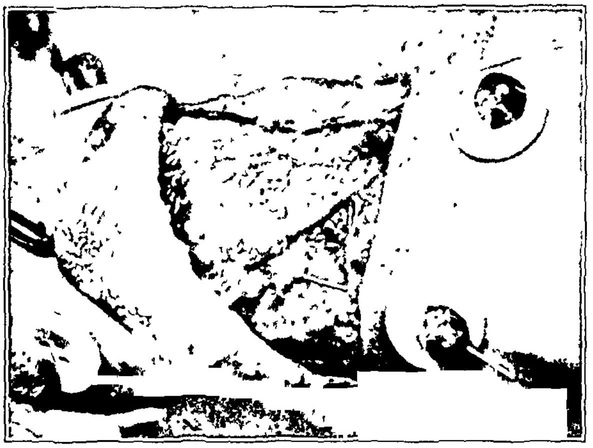

FIG. 8-B

Fig. 8-A: Before transplanting tendons for radial-nerve paralysis.
Fig. 8-B: After tendon transplantation. All the large veins have been retained. Subcutaneous fat covers the transplants. Wire has been used for tendon approximation.

modifications. The pronator teres is transplanted into the extensor carpi radialis longus and the extensor carpi radialis brevis. The flexor carpi ulnaris is transplanted into the extensor tendons of the long finger, the ring finger, and the little finger. The flexor carpi radialis is transplanted into the extensor pollicis longus and the extensor of the index finger (common extensor or extensor indicis proprius). The palmaris longus is transplanted into the abductor pollicis longus and the extensor pollicis brevis, as recommended by Bunnell (Figs. 7-A, 7-B, and 7-C).

If a transplantation is not made into the long abductor of the thumb, the thumb may ride too close to the index finger. In the absence of a palmaris longus, the authors transplant the flexor carpi radialis through the abductor pollicis longus, and then into the extensor pollicis longus and the extensor of the index finger. In spite of the difference in range of excursion of the thumb abductor and extensor, the results have been satisfactory.

Several points should be observed for optimum results. The pronator teres is transplanted through a separate incision. The authors have found that all three of the flexor tendons of the wrist can be detached and transplanted through one dorsal L-shaped incision. Through this approach, the tendons can readily be stripped back far enough by sliding curved scissors down along the tendon and muscle, and cutting all the fascial bands to permit a straight line of pull. When the L-shaped flap is being elevated, only the skin is lifted, and the veins and fatty layer are left intact. If the tourniquet is inflated soon after the arm has been elevated, and no constricting bandage is applied to empty the veins prior to inflation of the tourniquet, the veins will stand out and can easily be avoided. Two longitudinal incisions are then made through the fatty layer, and the transplantations are carried out. The layer of subcutaneous fatty tissue is then sutured together over the tendons. Thus normal fatty tissue surrounds the tendons,—a condition conducive to proper gliding of the tendons. Altman and Trott state that they have discarded dorsal L-shaped incisions because of postoperative oedema of the hand and sloughing of the corner of the L-shaped flap. The authors have not experienced either complication. We feel that preservation of the dorsal veins and the subcutaneous fat prevents postoperative swelling of the hand, and provides good gliding material around the site of the transplants (Figs. 8-A and 8-B). Sloughing at the corner of the incision can be avoided by cutting a rounded corner and by handling the flap gently. This flap is similar to a pedicle graft and, if cut and handled in a like manner, trouble will be averted.

The transplantations should be carried out with sufficient tension. Seldom will a radial transplant be too tight; on the other hand, it can be too lax. One of the authors' patients was operated upon elsewhere, and insufficient tension was put upon the tendons.

DISCUSSION

Dr. Sterling Bunnell, San Francisco, California: Repair of flexor tendons in the fingers is most difficult, and many surgeons are skeptical about its success. That good results can be obtained by adherence to these principles, which for many years I have been advocating, was demonstrated not by one, but by many of the officers assigned to that work in the Army. I have had the pleasure of seeing many of Dr. Graham's 141 cases of flexor repair; and I and many others can assure you that his results were excellent.

This short paper by Dr. Graham covered many of these principles which, if not observed, mean failure. If one operates with trauma, repairs tendons when joints are stiff, places junctures at wrong sites where they will adhere, disregards the gliding mechanism, or ignores the essential principles that should be adhered to, the tendon will become bound in its channel.

It has been found that a graft of a gliding assembly—that is, tendon plus paratenon, such as the palmaris longus—will usually give a much better result than will a smooth tendon graft, such as the sublimis with its epitenon.

There is a zone which I call "no man's land", where tendon junctures will adhere. It is between the distal crease in the palm and the middle crease in the fingers. When tendons are severed in this zone, the sublimis tendon must be removed.

By resorting to a tendon graft, we may place our tendon junctures where they will do no harm. The insertion in the last phalanx does not have to glide, and a juncture in the base of the palm or above the carpal ligament can glide. In the former instance, the lumbricalis is wrapped about the juncture, where it is naturally attached to the profundus tendon. Should a graft adhere, it often may be liberated by grafting paratenon or the slippery side of deep fascia beneath it. We should strive for a minimum of moving parts and a maximum of gliding material.

Dr. Luckey's paper tells of the types of tendon transfers commonly done in the various Army hospitals in World War II, and gives some valuable practical points gained from actual experience in the work.

All patients with lesions of arm nerves should, before dismissal, have orthopaedic consideration for possible tendon transfers.

Cases differ so much, in their bizarre combinations of paralyses, that one must leave the beaten paths of set methods and be guided by main principles. After the number of actions needed and the number of muscles available have been estimated, the available muscles should be divided up so as to supply the needs.

If active tendons are insufficient in number to move the various joints, as they are whenever any two of the three main nerves are cut, we should arthrodese the wrist. This makes some of the five wrist tendons available for use on the digits. If sufficient tendons are still not available, we should arthrodese enough joints so that the few tendons which we have will activate the remaining joints. We may thus solidify the wrist, the forearm in slight pronation, the base of the thumb by a bone block, or the middle joints of the fingers.

When there are insufficient active tendons, another procedure is to use the principle of tenodesis, which will furnish automatic motions. For instance, in paraplegia between the sixth and seventh cervical segments, the only motion of the hand is strong dorsiflexion of the wrist. Tenodesis of all digit flexors to the radius and of a tendon to the ulna which will draw the thumb into opposition will, when the wrist is extended, flex all digits and oppose the thumb.

The distance of excursion of transferred tendons is important. In the thumb, since the abductor has half the excursion of the long extensor, a single tendon joined to both cannot produce full motion. Wrist tendons which move one and one-quarter inches cannot impart full motion to digit extensors which normally move from two to three inches. Therefore, correction for radial palsy very rarely gives complete movement.

For paralysis of the intrinsic muscles of the hand, many different tendons can be used to restore muscle balance. Thus in paralytic claw-hand, the thumb is made to oppose and adduct, the index finger to abduct for pinch, and the metacarpal arch to curve. The finger clawing goes with restoration of muscle balance. These transfers have, as stated in this paper, been proved to be successful and practical.

Both of these papers are valuable and show what can be accomplished.

Dr. L. D. Howard, Jr., San Francisco, California: As far as the work of the Hand Centers during World War II is concerned, I think most of you are familiar with the general set-up of the program. Sometime in the latter part of 1944, Dr. Bunnell was asked by the War Department to be Chief Consultant in establishing these Centers throughout the country. Nine Centers were established. Dr. Bunnell's ability from a teaching and organizational standpoint can only be measured by the brilliant results obtained. There is an intense interest in this work by members of the orthopaedic profession, and rightly so. I believe it is important work, and I think all of you are taking active interest in getting better function of hands.

Dr. George S. Phalen, Cleveland, Ohio: Dr. Graham, Dr. Luckey, and Dr. McPherson are to be complimented on their presentations, as well as on the excellent manner in which they have restored these badly crippled hands to a state of usefulness.

We who were fortunate enough to have been stationed at Army General Hospitals which were designated as "Hand Centers" had the exceptional opportunity to see and treat a large number of hand cases. In a Har[illegible]

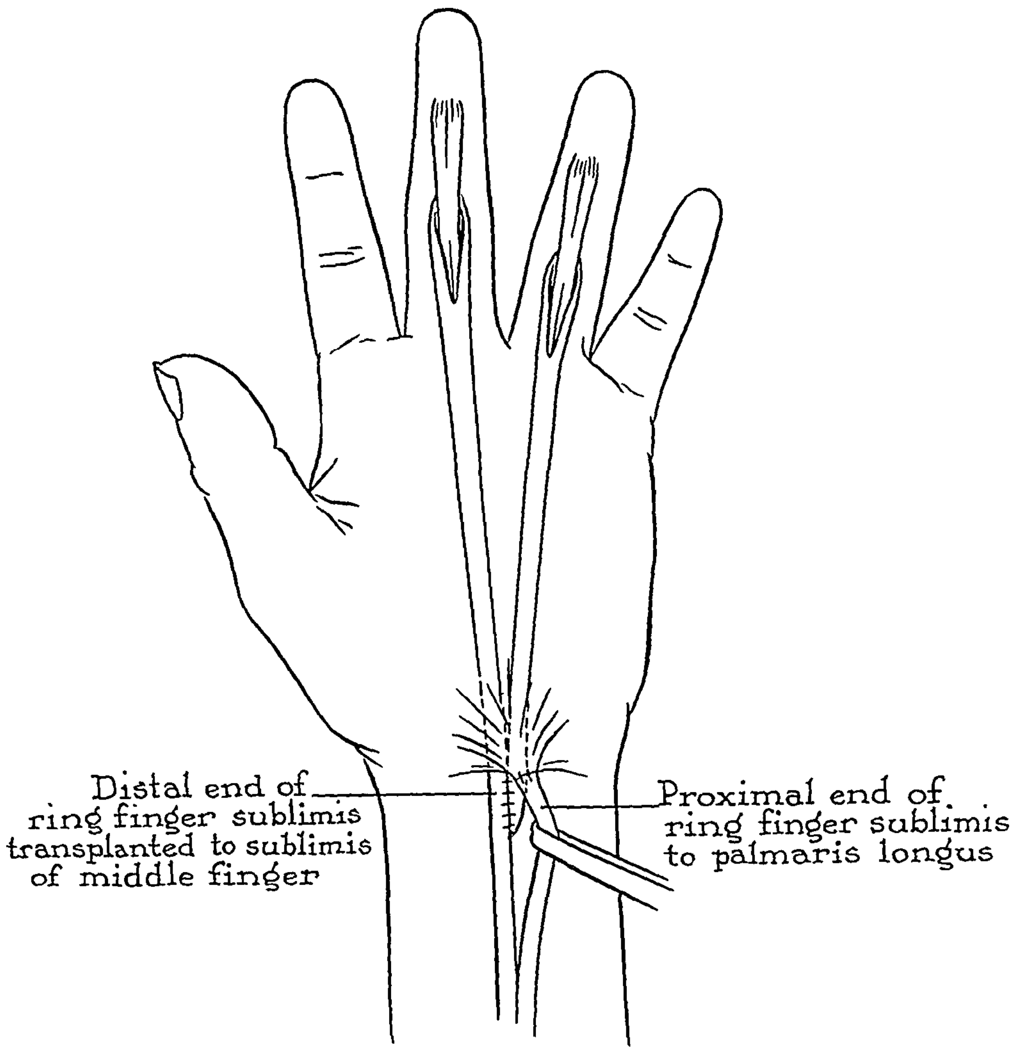

Fig. 10

For radial-nerve paralysis, all wrist flexors are transplanted posteriorly for extension of the digits; the sublimis of the ring finger is then transplanted to the wrist for stabilization of the wrist.

carried out at a later date, if the subject finds that his occupation demands a more stable wrist. To offset this objection to the transplant, the authors transplanted two sublimis tendons into the extensors, thus preserving at least one strong wrist flexor (Fig. 9-A). The sublimis muscles, however, have short tendons in the forearm, which do not lend themselves well to posterior transplantation; thus the extension which the patient obtained was somewhat limited (Figs. 9-B and 9-C). Then the usual transplantation for radial-nerve paralysis was carried out and, in addition, one or two sublimis tendons were transplanted into the wrist for flexors with, the authors feel, definite improvement in function * (Fig. 10). It must be remembered that the wrist muscles act not only to flex and to extend the wrist, but also to stabilize it. Therefore, anything which gives more stabilization on the flexor side of the wrist in these transplantations of radial nerve and tendon increases the power of the grip. Most of the individuals with tendon transplants for radial-nerve paralysis get along well without additional wrist flexors; nevertheless, when additional support is given, they are improved.

At Letterman General Hospital, tendon transplantations for radial-nerve paralysis have been carried out on forty-two patients. Of these cases, transplantations were done in thirty-one for complete radial-nerve paralysis, in seven for posterior interosseous paralysis, and in four for extensive tendon and muscle damage. The results have been

* Suggested in part by William H. Bickel, M.D., Rochester, Minnesota.

RECURRENT POSTERIOR DISLOCATION OF THE SHOULDER

BY J. C. R. HINDENACH, M.D., F.R.C.S., LONDON, ENGLAND

Posterior dislocation of the shoulder is a rare lesion. Thomas described seven cases, and stated that in 6,000 roentgenograms of the shoulder, four cases of posterior dislocation had been found. Fèvre and Mialaret found that out of every 100 recurrent shoulder dislocations, three were posterior, and that most of the recurrent cases were of congenital origin. The proportion of primary to recurrent lesions could not be ascertained.

The classification of the disability is confused. Möllerud quoted Blumensaat's classification of the patellar luxations, applying it to the shoulder:

1. Fresh luxations, arising in direct succession to an adequate trauma;
2. Recurrent luxations which occur more or less "spontaneously" now and then, at longer or shorter intervals, and are more or less sequelae of the primary luxation;
3. Permanent luxations:
   (a) Habitual (when the patella is luxated at every flexion of the knee joint), and
   (b) Constant (when the patella never occupies its normal place during any part of the movement of the knee).

The diagnosis of primary posterior dislocation of the shoulder is often missed, as the disability may not be severe, and the range of motion may be only slightly limited. Palpation of the head of the humerus below the spine of the scapula and the presence of an abnormal hollow below the acromion are the salient features. Anteroposterior roentgenograms are very misleading, because they may show a normal outline of the shoulder joint. Lateral views through the chest, or supero-inferior views through the axilla, display the abnormal position of the head of the humerus.

The recurrent and permanent types tend to become confused, and they overlap in the region of the shoulder. Argument has arisen over the distinction between the recurrent and the permanent habitual classes. A shoulder may be dislocated posteriorly by trauma, and although adequate reduction may be performed, the dislocation may recur every few months following specific strain. This is a true recurrent type. However, following an original dislocation, the disability may recur every time the arm is abducted, or flexed and elevated. Such a condition, although recurrent, is also habitual. True habitual posterior dislocation of the shoulder, however, often occurs in young adults without history of primary injury, and it is commonly bilateral.

Short summaries of some of the cases reported may clarify the classification. Rowe and Yee described a posterior approach to the shoulder, and gave case reports of two soldiers, each with a similar lesion. Both men were twenty-two years old, of good muscle development; they had sustained original injuries to their shoulders, which resulted in posterior dislocations. Following reduction, there were numerous recurrences, until the disability recurred every time the affected arm was flexed and elevated. When the muscle was relaxed, or when traction was applied to the arm, the shoulder returned to normal. A Nicola operation which was performed upon one patient had produced no improvement. Both patients were operated upon through a posterior approach, the labrum was sutured to the bone (Bankart's technique), and full function was restored.

Möllerud reported a girl of eighteen years who had noticed a slip in the left shoulder for several years, and in the right for about two. When the left arm was stretched forward and upward and rotated medially, the head of the humerus slipped backward, and could be felt under the spine of the scapula. When the arm was brought back to the normal position, the bone returned to its place with a jerk. The shoulder luxation could not be pro-

considerable scarring and fibrosis about the base of the thumb metacarpal. This is due to direct trauma, to prolonged immobilization, or to Volkmann's ischaemia. Excision of the scar about the base of the metacarpal, followed by extensive active and passive motion, produced improvement in some, while osteotomy of the metacarpal has been necessary in other cases.

Observation of a relatively large number of median-nerve injuries revealed that, in addition to lack of return of intrinsic-muscle function, there frequently was little or no return of function in the flexor pollicis longus. This was true even after a prolonged period had elapsed since the nerve repair. Flexor pollicis longus action is restored, as described previously (Figs. 4-A, 5-B, and 6-A). Activity of the long flexors in cases of high irreparable lesions of the median nerve is restored by utilizing the remaining active and available long muscles of the forearm, as was described originally by Stiles and Forrester-Brown.

PARALYSIS OF THE MEDIAN AND ULNAR NERVES

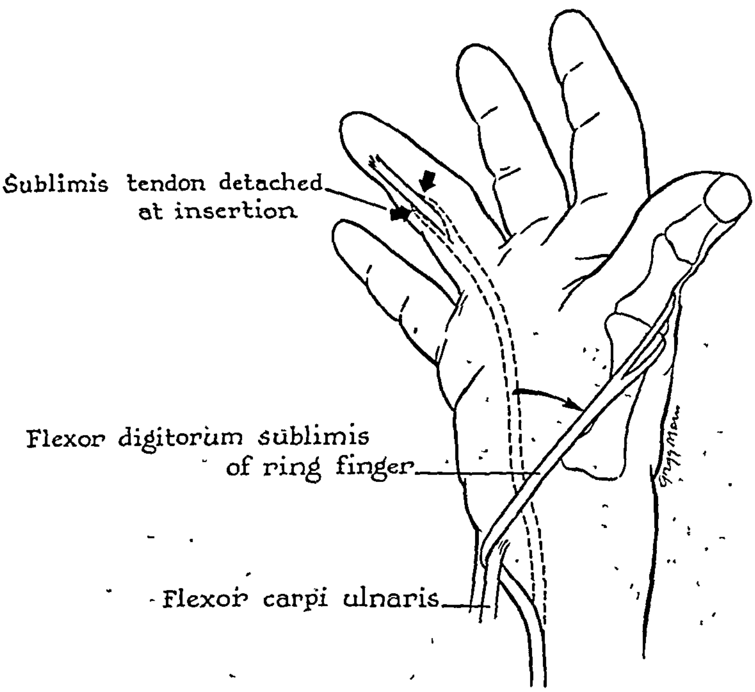

Fig. 13

Fig. 13: Modified Royle procedure for paralysis of opponens pollicis. Flexor digitorum sublimis of ring finger is looped around flexor carpi ulnaris, transplanted subcutaneously across thenar eminence, and sutured into thumb metacarpal and proximal phalanx. If this procedure is used, the slip to the phalanx must be sufficiently taut so that the metacarpophalangeal motion will be utilized, as emphasized by Bunnell.

Irreparable lesions of the median and ulnar nerves above the forearm produce a severely crippled hand. In many cases, suture of these nerves is satisfactory, and function returns to the long flexors. In the authors' experience, however, the intrinsic muscles of the hand seldom regain satisfactory function, so that the methods described by Bunnell must be employed for restoration of normal function. In the cases of irreparable injury, one utilizes the muscles supplied by the radial nerve [6, 14]. In order that all the wrist extensors may be used, the wrist should be fused. If it is fused in too much dorsiflexion, the transplanted tendons do not seem to flex the digits well. The authors arthrodese the wrist in the manner described by Abbott, Saunders, and Bost. This procedure retains motion at the carpometacarpal joint, which the patients find very useful because it permits the palm to be mobile.

After the wrist has been fused, all three of the dorsiflexors of the wrist and the brachioradialis can be used for flexion of the digits and opposition of the thumb. The authors first transplanted the extensor carpi radialis longus into the flexor pollicis longus and the flexor digitorum profundus of the index finger, and the extensor carpi radialis brevis into the flexor digitorum profundus of the long finger, ring finger, and little finger. The most difficult task was to get the thumb to move in a proper functional relationship to the fingers. The interphalangeal joint of the thumb had a tendency toward excessive flexion, in spite of adjustment of tension of the transplant and re-education of the patient. To overcome this objection, the authors have transplanted the brachioradialis to the flexor pollicis longus, and the extensor carpi radialis longus and extensor carpi radialis brevis into the

can be inspected. If no further abnormality is seen, some posterior support to the joint must be provided. Kaplan has treated two cases by using a "reversed Clairmont operation", bringing a portion of the anterior deltoid through the quadrilateral space to be attached posteriorly. He reports good results.

A more stable support can be obtained by using a posterior bone graft. Rocher has used a tibial graft, inserted extracapsularly under the infraspinatus and projecting four millimeters laterally beyond the glenoid. Fèvre and Mialaret have obtained their grafts from the eighth rib posteriorly, splitting it longitudinally into two and inserting both grafts deep to the infraspinatus. They completed the operation by fixing the arm in plaster in a position of abduction and external rotation. This position puts little strain upon the posterior aspect of the joint.

Ilfeld and Holder treated anterior recurrent shoulder dislocation with a graft from the ilium, employing one-half of the thickness of the iliac crest and the outer cortex of the ilium. The graft, two by one and one-half inches, is naturally curved to fit the glenoid neck. It can be fixed against the "rawed" bone with a Vitallium screw, and lies extracapsularly, being allowed to project four millimeters laterally. The arm is fixed to the side for six weeks.

The congenital type of recurrence is usually due to an abnormal glenoid fossa, and a posterior bony buttress offers the best chance of cure. Tibial and split-rib grafts have been used with success. Ombrédanne employed an ingenious technique in a baby of twenty months. He freed the spine of the scapula from muscles, hinged it close to the great scapular notch, and swung this osteoplastic flap deep to the infraspinatus so that it lay posterior to the joint capsule. He suggested, however, that this method, although suitable in the young whose bones are still malleable, would probably not be applicable to an adult.

The old unreduced dislocation (the constant, permanent type) forms a good bony buttress for itself on the dorsum of the scapula. Limitation of shoulder range is not great, and treatment is unnecessary.

CASE REPORT

G.B., a prisoner of war, twenty-four years of age, fell on his right shoulder in April 1944, while doing physical training. He was unable to elevate his arm, and was treated with physiotherapy in a camp reception station for one month without improvement. Roentgenograms were normal. In May he was operated upon, presumably for a ruptured supraspinatus muscle. Again, there was no improvement. An anterior approach to the joint was made in September 1944, and the outer end of the clavicle was removed. Repeated posterior subluxation followed, and a Nicola operation was performed in June 1945. In spite of this, there was no improvement in function. On November 20, 1945, the patient was admitted to a British Military Hospital. Physical examination showed a well-built muscular young man. The right shoulder had three long interlacing

FIG. 1

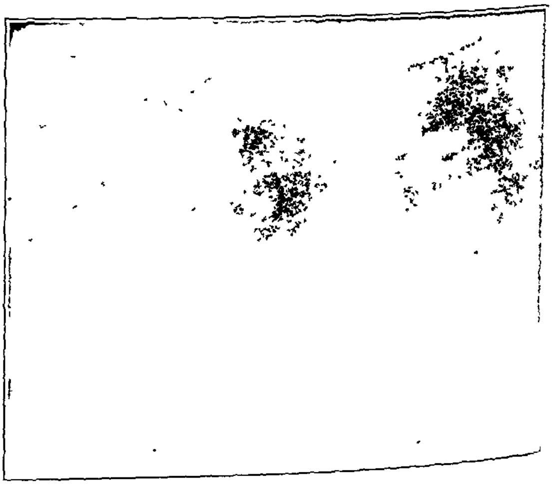

FIG. 2

Fig. 1: Supero-inferior view through axilla, showing head of humerus in normal position.
Fig. 2: Supero-inferior view with humeral head subluxated posteriorly.

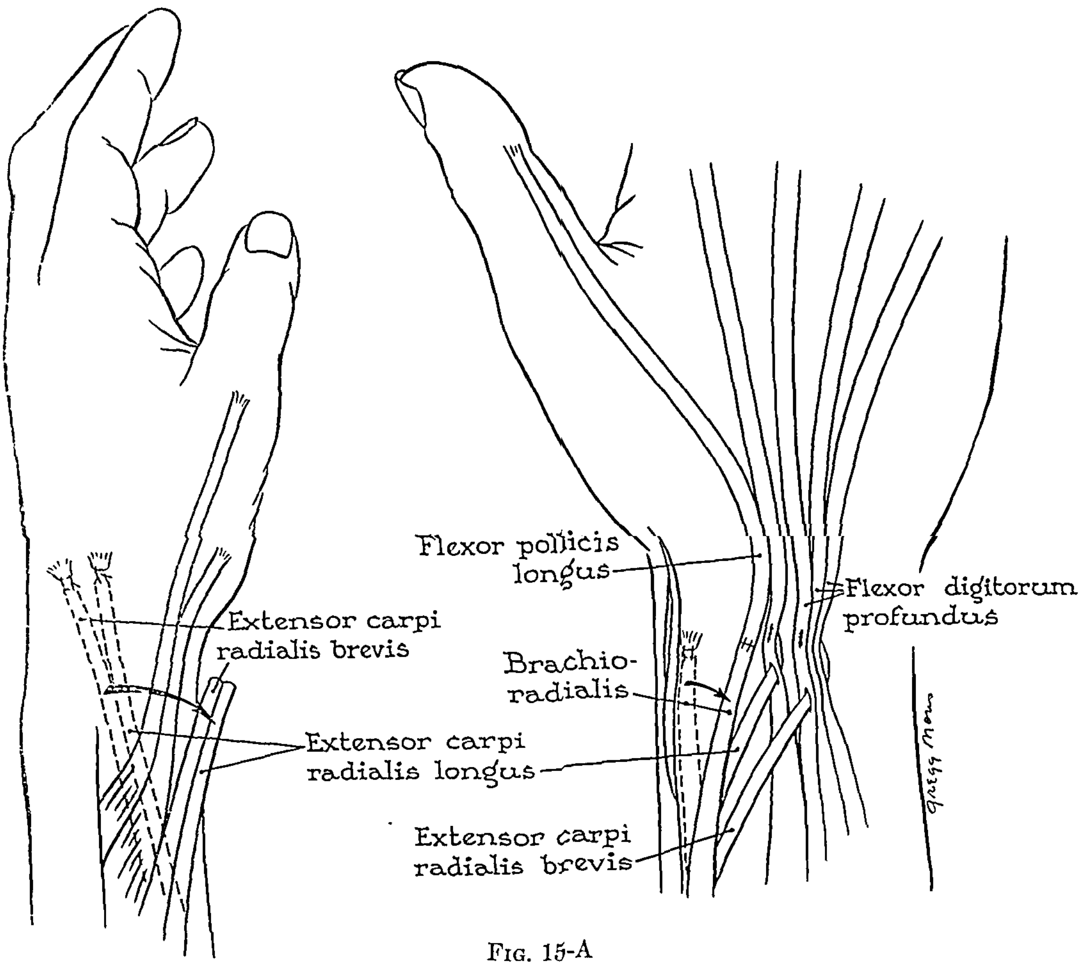

FIG. 15-A

Modified Bunnell procedure for correction of paralysis of median and ulnar nerves includes the following steps:
1. Arthrodesis of wrist.
2. Extensor carpi radialis longus is transplanted into flexor digitorum profundus of index finger.
3. Extensor carpi radialis brevis is transplanted into flexor digitorum profundus of long finger, ring finger, and little finger.
4. Brachioradialis is transplanted into flexor pollicis longus.

To restore opposition of the thumb, the extensor pollicis brevis tendon is detached proximally, transplanted subcutaneously across the thenar eminence, as shown in Figure 14-A, and sutured to the extensor carpi ulnaris, which is transplanted around the ulnar side of the forearm[6].

The range of the wrist extensors is approximately one and one-quarter inches; the long flexors of the fingers glide through a range of two and three-quarters-inches, according to Bunnell. With this in mind, the proper tension of the transplants should be determined. The fused wrist provides an advantage, since all the motion will be in the finger joints and none will be taken up by a mobile wrist. If the tension is too great, there will be excessive clawing, and the thumb and fingers will not come together in a functional position. On the other hand, excess length will allow for complete extension, but will not permit enough flexion for a satisfactory grasp. The authors feel that the tension should be such that the proximal two joints would be permitted to extend to about 140 to 150 degrees at the time the transplantation is done, and the distal joint would be permitted to extend to about 160 degrees. The tension on the transplant for thumb opposition should be too much rather than too little.

In two of the authors' cases of paralysis of the median and ulnar nerves, extensive fibrosis of the flexor muscles in the forearm and of the intrinsic muscles of the hand was also present. In spite of extensive excision of scar tissue around the base of the thumb, the

This case has some noteworthy features. Although related originally to an injury, the disability became immediately habitual. Despite the traumatic history, no lesion of the labrium glenoidale was found. It is the second such case reported in which a Nicola operation has been unsuccessful.

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likely possibility. This procedure should not be entered into hurriedly; if, at a later date, the patient finds that the clawing interferes with his work, the joint can then be fused.

Slitting the pulleys at the base of the fingers to permit some bowstringing of the tendons and a more effective pull [6] has been done in one case. It has not resulted in any functional advantage, as far as the authors have been able to determine.

INJURIES TO THE BRACHIAL PLEXUS

Injuries to the brachial plexus have been relatively frequent, because of the exposure of the shoulder on the battlefield. Neurosurgeons have been able to repair many of these, and the return of function has been surprising in some instances. In others, there is a spotty return of function; and reconstruction depends upon the muscles available and their use in one of the ways described previously. Stiles and Forrester-Brown state that the varieties of transplants used for incomplete injuries are almost as numerous as the tendons. Sometimes all the nerves show evidence of return of function, but the end result is excessive weakness of all the muscles. *In these instances, arthrodesis of the wrist materially increases* function, since all the motion is then transmitted to the finger joints. In addition, if the wrist flexors or extensors, or both, are functioning, they are then available for transplants.

CONCLUSIONS

Most of the reconstructive procedures of the hand which are employed in permanent nerve paralysis, discussed in this paper, have been employed previously, but some of them are new. For a transplantation to be successful, one must first mobilize the joint, eliminate scar tissue, and then transplant a normally functioning tendon and muscle through normal tissue. *Flexors can be transplanted to extensors and extensors to flexors*, with excellent results. In most instances, the muscle transplanted should be the one which is most readily available and which has a range of motion as nearly as possible like that of the muscle and tendon it is intended to replace.

NOTE: All the hand drawings were made by Gregg Moris, Medical Artist at the Letterman General Hospital. The photographs were taken by the Photographic Laboratory, Letterman General Hospital.

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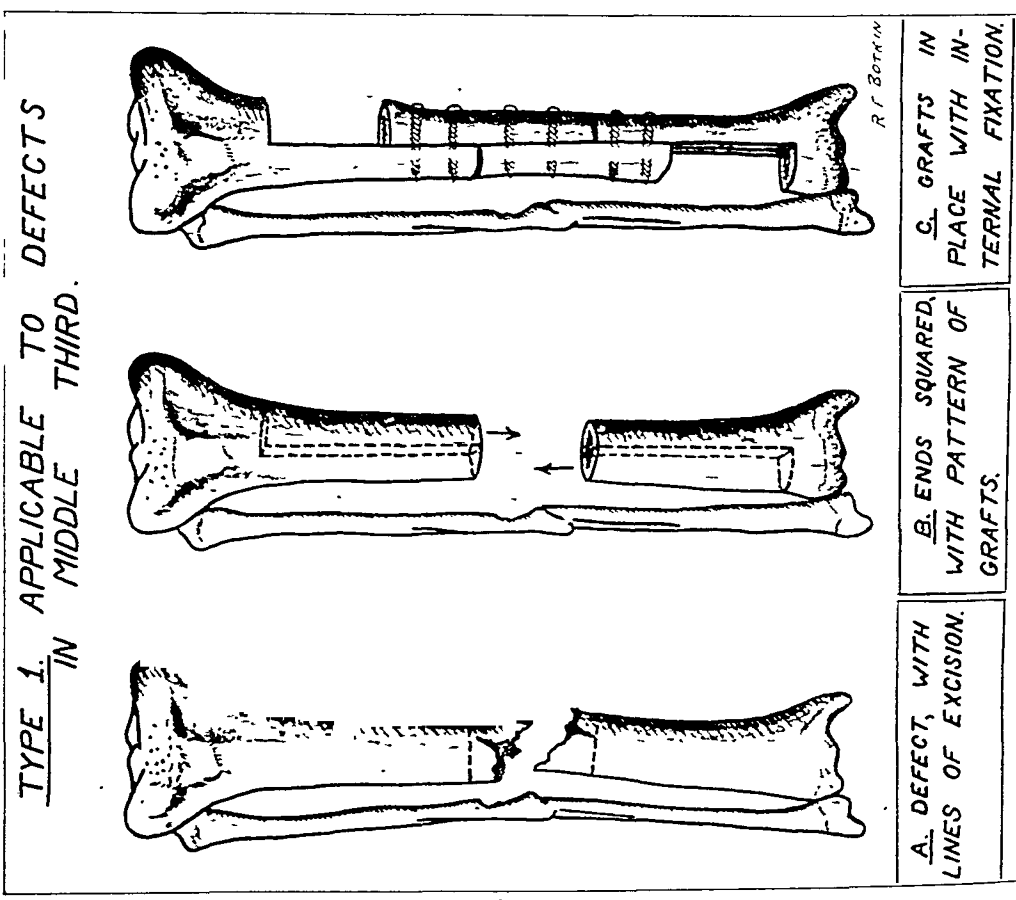

Fig. 1-A
Type 1 procedure.

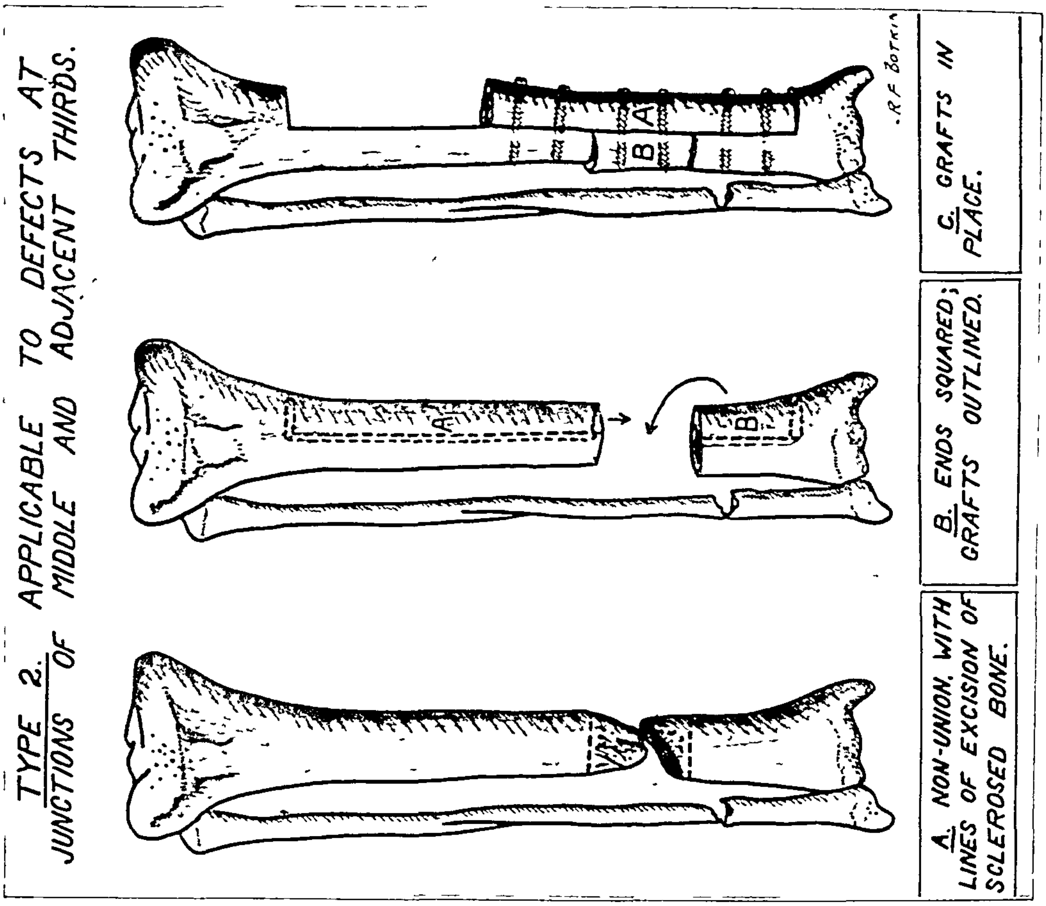

Fig. 1-B
Type 2 procedure.

Center which was also a Neurosurgical Center, there were numerous cases of irreparable nerve injury; and almost all of these cases required some type of tendon transfer to restore efficiency to the paralyzed hands.

The tendon transfer for radial-nerve paralysis is the one which is probably used most widely; and the end results from this tendon transfer are almost universally good. I agree with Dr. Luckey that it is most important that the transferred flexor tendons in these cases of radial-nerve palsy be placed under considerable tension. The effective range of motion in the wrist and hand should be largely above the horizontal plane. With the wrist extended about 30 degrees, the patient should be able to extend the fingers to the plane of the palm and to flex the fingers into a firm fist. When the transferred tendons are placed under such tension, the patient is no longer able to make a fist with the wrist flexed; but this, of course, is not a purposeful or useful movement and causes no disability.

We preferred to transfer the flexor carpi radialis into the long abductor and the two extensors of the thumb, leaving the extensor tendon of the index finger to be included with the other finger extensors in the transfer of the flexor carpi ulnaris. In all cases of irreparable damage to only the deep branch of the radial nerve, we did what we called a "triple transfer at the wrist": The flexor carpi ulnaris was used to motivate the finger extensors, the extensor carpi radialis brevis was used to activate the long thumb extensor, and the palmaris longus was transferred into the long abductor and short extensor of the thumb. In this manner, the flexor carpi radialis was left undisturbed and served to stabilize the wrist.

In the restoration of function in these tendon transfers, the patient's condition must be checked frequently to be sure that a tenodesis action is not being substituted for a true contraction of the transferred muscle. For example, a patient with a transfer of the flexor carpi ulnaris into the extensor digitorum communis will soon find that permitting his wrist to flex will automatically cause extension of his fingers, due to the checkrein effect of the transfer of the flexor carpi ulnaris. He will find it easier to extend his fingers by this "checkrein" effect than by actually contracting the transferred tendon. Occasionally, galvanic stimulation of the transferred muscles will give the patient the "feel" of the muscle now performing an entirely new function, and this may better enable him to re-educate himself.

I believe one cannot stress too strongly the importance of joint mobilization prior to tendon transfer or tendon grafting. Certainly if the fingers cannot be flexed and extended passively, no tendon graft or transfer will ever restore these functions. Fortunately, in peripheral-nerve injuries there is frequently little or no damage to the hand itself; but the hand may have become stiffened from circulatory impairment, from trophic changes, or from prolonged splinting of a fracture of the forearm or upper arm. These hands *must* be mobilized as completely as possible prior to any tendon transfer. This sometimes implies that operative steps must be taken prior to the transfer, such as capsulectomy of the metacarpophalangeal joints, adductor stripping of the thumb, tenolysis,—especially of the extensor tendons, or application of a skin graft to supply the necessary mobility of the involved joints. The performance of such operations at the same time as the tendon transfer is not advisable.

In incomplete median-nerve paralysis, there may be return of some power in the finger flexors, but this power may not be sufficient to give the patient an adequate grip. Reinforcement of the finger flexors may be carried out by transfer of either a wrist flexor or a wrist extensor muscle into the finger flexors. Extension of the wrist and flexion of the fingers is more of an associated movement than is flexion of the wrist and flexion of the fingers. In the cases in which fusion of the wrist was not advisable, we found that better strength in flexion of the fingers was obtained by transferring the extensor carpi radialis longus or brevis into the finger flexors than by using the flexor carpi radialis.

I believe it is important, before performing a flexor-tendon graft, to explain to the patient just what may be expected from this operation. The patient usually anticipates that the finger will function again in a perfectly normal manner, although actually—even with the very best tendon graft—he will never be able to strongly clench the finger down into the palm. If he is able even to touch the tip of the finger to his palm, the result is considered excellent.

If arthrodesis of the wrist is included in the reconstruction program outlined for a particular hand case, I believe this operation should be postponed until after the flexor-tendon graft has been done. Flexion of the wrist at the time of the flexor graft aids considerably in determining the degree of tension on the graft, and prevents flexion contracture of the finger, which may develop with too much tension.

Dr. Walter C. Graham, Santa Barbara, California (closing): I want to thank the discussors. Dr. Phalen brought out a very important point which should be stressed, and that is the complete mobilization of the joints before tendon-grafting. It is important that no tendon graft be done to a finger which is without sensation. The effort of the patient following operation is the most important single point in restoring function.

Dr. C. A. Luckey, Oakland, California (closing): I want to thank Dr. Bunnell, Dr. Howard, and Dr. Phalen for their remarks. Dr. Phalen has emphasized his work of transplanting the extensors into flexors, and we thoroughly agree with him. In the presence of a fused wrist, one can transplant wrist flexors into digit flexors with reasonably good results. However, if the wrist is not fixed and if the wrist flexor is used to activate a digit flexor, there will be difficulty in getting as much motion as one would like to have.

the deep cortex. The grafts are then rebedded according to plan and fixed firmly with engaging screws. The periosteum is carefully closed over the proximal and distal fragments to the site of the defect, where the periosteum is non-existent. Further closure is routine, and external plaster fixation is applied.

The use of iliac-bone chips to fill residual donor defects in order to accelerate osteogenesis was first suggested to the authors by Sterling Bunnell. Since then, iliac-bone blocks and chips have been used successfully, not only to fill donor defects, but also to fill in the opposite half of very large defects, after the main fragments have been bridged and firmly immobilized by the use of a single massive half-cylinder graft from the affected bone. It has been found that this iliac bone is revitalized rapidly, and that the resulting osteogenesis is accelerated and more complete than in those cases in which the defect is allowed to become filled in unaided (Fig. 1-D).

POSTOPERATIVE CARE

After reconstruction of the tibia, a single plaster hip spica is applied and is maintained for ten weeks, followed by the application of a toe-to-groin walking plaster. The walking plaster, in turn, is removed in eight weeks, followed by the use of a toe-to-groin brace or another walking plaster, depending upon the progress of healing. In femoral cases, a double hip spica is applied and is maintained for twelve weeks. The plaster is then removed and the affected extremity is placed in traction and suspension, in order to obtain mobilization of the joints and reconditioning of the extremity as a whole.

RECONDITIONING OF THE PATIENT AND OF THE AFFECTED EXTREMITY BEFORE OPERATION

Although problems of elimination of infection and repair of skin defects are not within the scope of this paper, treatment of these complications, and the physical reconditioning of the patient[7], as well as of the involved extremity, are equally as important as the reconstruction surgery which follows. The degree of success of the reconstruction surgery is in direct ratio to the physical condition of the patient and of the extremity at the time

FIG. 2-A

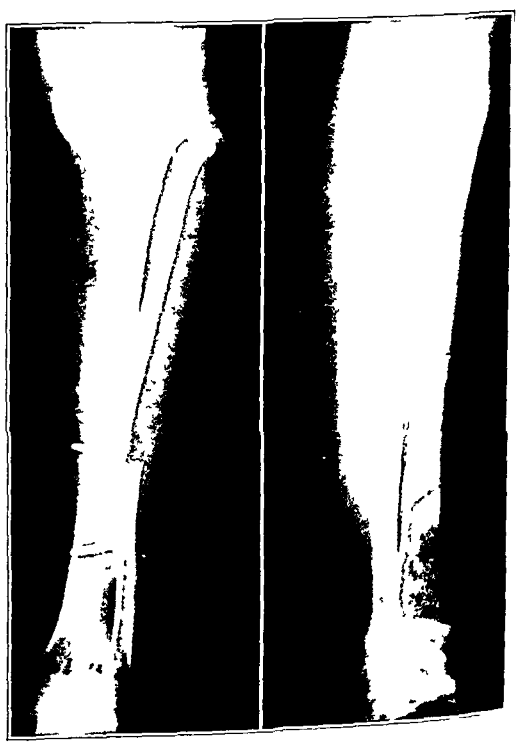

FIG. 2-B

FIG. 2-A: Case 2, J. S. Preoperative bone defect.
FIG. 2-B: Anteroposterior and lateral views, five months and twenty-three days after operation by the Type 1 procedure.

duced, when the arm was rotated externally. The right shoulder had a similar tendency, which was not so pronounced. Roentgenograms were normal.

Sjövall's case was a man of twenty-two years who had had discomfort in his shoulder for two years, and could produce backward luxation by stretching his arm forward and upward in internal rotation.

Asplund described a boy of eighteen years of age in whom backward luxation resulted when his right arm was abducted to 50 degrees and then stretched forward during simultaneous internal rotation. This applied to both shoulders. It was suggested that during internal rotation the external rotator muscles failed to act as a posterior brace to the head of the humerus. In the roentgenograms a flat posterior part of the glenoid was visible, and arthrography showed a large posterior recess. At operation the labrium glenoidale was absent on one side. A posterior bone graft, projecting from four to five millimeters laterally, was inserted with good results.

Asplund stated that his case was that of a "*schnappender Schulter*", or "snapping shoulder", and that it was voluntary and habitual. Voluntary is described as being related to an act, habitual to a frailty. Möllerud, however, considers that Asplund's case was truly recurrent and not habitual, and his point of view is probable because at operation the labrium glenoidale was absent, thus suggesting a primary traumatic factor.

Congenital posterior dislocation of the shoulder has been described by several French writers. The primary lesion is commonly a small glenoid fossa. Ombrédanne states that, unlike congenital dislocation of the hip, the condition in the shoulder cannot be cured by reduction and adequate retention in the normal position. Posterior slipping always occurs. Various bone-graft operations have been used in its repair.

TREATMENT

Usually the true recurrent type of posterior dislocation which is due to trauma has a detached labrium glenoidale. Bankart's method of repair gives good results. The approach to the joint is well described by Rowe and Yee, who dealt with two cases, and by Harmon, who modified the technique slightly. An incision is made from the middle of the scapular spine along and just inferior to it as far as the tip of the acromion. The origin of the deltoid is dissected subperiosteally from the spine, and the muscle flap is freed from the deeper structures, and reflected laterally and inferiorly. Care is taken not to exert gross traction or to use deep retractors, for the circumflex nerve may be damaged. The bellies of the infraspinatus and the teres minor are thus exposed, and then separated, and the latter is retracted. Therefore, the contents of the quadrilateral space are protected. The attachment of the infraspinatus is divided one-half inch from its insertion into the greater tuberosity of the humerus, and is reflected medially from the underlying capsule and scapula. The region of the great scapular notch with the terminal branches of the suprascapular nerve must be avoided. An excellent view of the entire posterior aspect of the shoulder capsule is obtained. When trauma has been the cause of the lesion, the capsule with the labrium glenoidale will be found detached from the posterior margin of the glenoid fossa. A method similar to that used by Bankart for anterior recurrent dislocations may be used to repair the lesion. The posterior surface of the glenoid neck and rim is "rawed", and four or six drill holes are bored through the rim. The drilling is simpler here than in the anterior part of the joint. The approach is direct, and an angled drill is unnecessary. The capsule is reattached to the scapular neck by mattress sutures through the drill holes. The cut tendon of the infraspinatus is sutured, the deltoid is reattached to the spine of the scapula, and the skin is closed. The flexed arm is bandaged to the side for six weeks, with the wrist and fingers left free. Active movements are then encouraged.

In the voluntary or habitual type of recurrent dislocation, no detachment of the labrium glenoidale may be found. Often a general bulging of the capsule is observed. The capsule should be incised vertically one-third of an inch from the glenoid, so that the joint

was admitted on August 27, 1944. He had a draining compound wound and loss of bone substance, involving the middle third of the left tibia, as a result of shell-fragment wounds incurred on July 12, 1944, at Saint-Lô, France. Draining had subsided and the wound had healed by January 15, 1945. Excision of the cicatrix and primary closure of the anterior aspect of the left leg were performed on March 6. An apposing massive bone-graft operation was performed on April 17. Weight-bearing in a walking plaster was begun on August 17, and the walking plaster was changed on October 15. Solid union was established. The length of the defect bridged was three and one-eighth inches. Residual shortening of the affected tibia measured one and one-half inches.

CASE 4. A private, twenty-eight years of age, was admitted on November 28, 1944. He had a draining compound wound and loss of bone substance, involving the lower third of the left tibia, in addition to other injuries, as the result of a shell-fragment wound incurred on August 15, 1944, in France. Draining subsided and the wound had healed by December 11. A reconstruction of the tibia with massive apposing bone grafts was performed on April 21, 1945. Weight-bearing in a walking plaster was begun on August 17. The soldier was fitted with a toe-to-groin brace on October 27, at which time union was completely solid. The length of the defect bridged was two and three-eighths inches. No shortening of the involved tibia resulted.

CASE 5. A first lieutenant, twenty-six years old, was admitted on April 8, 1945. He had a healed compound wound with loss of bone substance, involving the left tibia at the junction of the middle and lower thirds, as a result of a plane crash in France on December 11, 1944. Drainage ceased, and the wound had healed by January 11, 1945. A reconstruction with massive apposing bone grafts was performed on June 19, 1945. Ten weeks after operation, on August 28, the hip spica was removed and a toe-to-groin walking plaster was applied, at which time union was firm but not solid. The walking plaster was changed eight weeks later, on October 23, at which time union was solid. A toe-to-groin brace was applied on December 28. The length of defect bridged was one and one-eighth inches. There was no residual shortening of the involved tibia.

CASE 6. T. H., a twenty-year-old private, was admitted on June 4, 1945. He had a healed compound wound of the right thigh, with non-union and loss of bone substance, involving the right femur at the junction of the middle and lower thirds, as the result of a gunshot wound by enemy action in Aachen, Germany, on November 17, 1944. The wound had healed by December 1944 (Fig. 3-A). A reconstruction with apposing massive bone grafts was performed on August 1, 1945. On November 9, a double hip spica was removed, and the extremity was placed in balanced traction and suspension; at that time union was clinically solid. An ischial weight-bearing brace was applied on December 28, and the patient was able to be ambulatory. The

FIG. 3-A

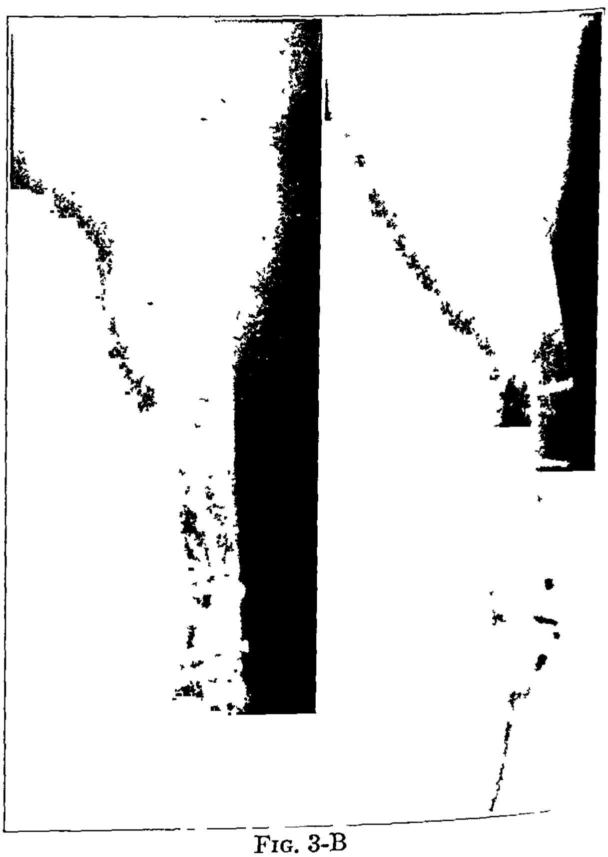

FIG. 3-B

Fig. 3-A: Case 6, T. H. Preoperative bone defect of femur.
Fig. 3-B: Anteroposterior and lateral views, seven weeks after operation by the Type 2 procedure.

scars anteriorly and superiorly. The deltoid and all other shoulder muscles contracted strongly and actively. Passive shoulder range was limited, probably by capsular scarring from previous operations. Passive abduction was possible to 150 degrees, and elevation to 150 degrees. External and internal rotation were complete. Upon active abduction at 30 degrees, the head of the humerus was felt to slip posteriorly, and after this no further abduction was possible. A similar result followed attempted forward flexion of the shoulder. With the arm at the side, the humeral head could be made to slide posteriorly by pressure from in front. Anteroposterior roentgenograms showed a normal shoulder joint, with the outer end of the clavicle absent. Supero-inferior views through the axilla showed how the head of the humerus could be made to alter its relationship with the glenoid fossa (Figs. 1 and 2).

A diagnosis of recurrent posterior subluxation of the humerus was made, and a posterior bone-buttress operation was decided upon.

On November 26, 1945, the right shoulder joint was approached posteriorly, according to the method described by Harmon. Upon reflection of the infraspinatus, the joint capsule appeared grossly lax. The capsule was incised vertically, and the interior of the joint was inspected. The labrium glenoidale was seen intact and firmly attached to the glenoid rim. The tendon of the long head of the biceps could be identified, passing from its origin to enter the head of the humerus. This band, however, failed to prevent the head from sliding backwards when it was forced from the front. The capsule was closed by reefing with mattress sutures. An iliac graft, two inches by one and one-half, was removed from the right side of the pelvis. The graft consisted of half of the thickness of the iliac crest and the outer cortex of the ilium. With a chisel, the outer cortex of the posterior aspect of the glenoid rim and of the neck of the scapula was removed, leaving a raw bed of cancellous bone against which the iliac graft was fitted and fixed firmly by a short Vitallium screw. The graft projected laterally and extracapsularly for one-third of an inch. The infraspinatus was replaced over the graft, and its tendon was sutured. The deltoid was reattached to the spine of the scapula, and the skin was closed. The arm was bandaged to the side with the elbow flexed to 60 degrees, the wrist and fingers being left free. This position was maintained for six weeks, and then active movements were begun. Postoperative shock and discomfort were negligible.

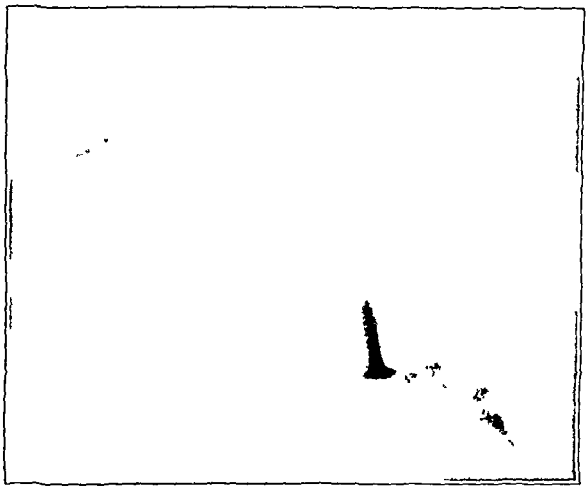

FIG. 3

Supero-inferior view six weeks after operation, showing graft and screw.

FIG. 4-A

Fig. 4-B

Six months after operation, showing union and smoothing of the graft.

On January 15, 1946, the patient could raise his arm more than 90 degrees, and he stated that the shoulder felt stable for the first time in nearly two years. Roentgenograms showed the graft in position (Fig. 3).

A personal communication from Lt. Col. Darling, R.A.M.C., then in charge of the patient, stated that in July 1946, the patient was almost normal. He had had no further subluxations. The right arm could be raised slightly less than 180 degrees, and there was a full range of motion in all other directions. The man himself was well satisfied, and was doing his normal work as a carpenter.

Roentgenograms at that time showed that the buttress had been molded to adapt itself to the shape of the head of the humerus (Figs. 4-A and 4-B).

sequestrectomies were performed elsewhere on November 2, 1943, and on February 24, 1944, and healing of the wound had occurred by August 1944. The scar was excised with primary closure on February 19, 1945. A modified reconstruction, which consisted of bridging of the defect with a half-cylinder graft and an apposing block of iliac bone, was performed on August 31. The hip spica was removed on December 5, and a toe-to-groin walking plaster was applied; at that time, union was clinically solid. The length of the defect bridged was two and seven-eighths inches. Residual shortening of the left lower extremity measured one-half inch.

Fig. 4-E
Anteroposterior and lateral views, eight months after the operation.

Case 8. F. B., a private, thirty-four years old, was admitted on November 2, 1944. He had a draining compound wound, involving the right lower leg, and non-union with a bone defect of the lower third of the right tibia, as the result of the explosion of a land mine near Florence, Italy, on July 1, 1944. Sequestrectomy was performed elsewhere on October 16, 1944. Saucerization was carried out on January 12, 1945, with healing of the wound by March 1. The scar was excised with primary closure on July 25, 1945 (Fig. 4-A). A reconstruction with apposing massive bone grafts was carried out on September 7, and the residual donor defect was filled with iliac-bone chips (Fig. 4-B). The hip spica was removed, and a toe-to-groin walking plaster was applied on December 5, at which time union was clinically solid (Fig. 4-C). The length of the defect bridged was two inches. Residual shortening of the right lower extremity measured one-half inch.

Case 14. T. C., a sergeant, twenty-four years old, was admitted on June 15, 1945. He had a draining compound wound, involving the left lower leg, and non-union associated with a bone defect which involved the left tibia at the junction of the middle and lower thirds, incurred when the patient was struck by exploding mine fragments, near Zerf, Germany, on March 17, 1945. Healing of the wound had occurred by August 28, 1945. Reconstruction with apposing half-cylinder grafts and filling of the residual donor defects with iliac chips were performed on December 5, 1945. The hip spica was removed and a toe-to-groin walking plaster was applied ten weeks after operation; at that time, union was clinically firm. Twelve weeks later (twenty-two weeks after operation), the plaster was removed; and union was found to be solid. A supporting toe-to-groin brace was applied. The length of the defect bridged was one and five-eighths inches. Residual shortening of the tibia measured seven-eighths of an inch.

SUMMARY

This report is based on the end results in the first eight cases, seven tibiae and one femur, treated by this method between December 15, 1943, and September 7, 1945. In all of these cases, bridging of the defects and union of the affected bones were accomplished successfully without the sacrifice of bone length. Since this time, similar procedures have been employed in thirteen additional cases (ten tibiae and three femora). Of the twenty-one patients operated upon, there were sixteen successful end results, one refracture twelve months after operation, and four failures due to recurrence of the infection after operation. Two of these failures resulted from infection, secondary to necrosis of scar tissue, adjacent to the operative field. In the other two cases of infection, drainage occurred postoperatively through the operative site. The case with refracture and the four cases of postoperative infection are classified as failures. In the twelfth patient operated upon, the complication of fracture of the sound portion of the proximal fragment of the femur at the site of the crosscut occurred during the operation. This was the result of abnormal leverage in the act of reducing the fragments. It necessitated the application of a lateral bone plate at the site of fracture, and prolonged the operative procedure considerably. Caution is advised, therefore, in the reduction of the fragments and rebedding of the grafts.

RECONSTRUCTION OF DEFECTS OF THE TIBIA APPOSING MASSIVE GRAFTS FROM THE AF

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Bone defects of the tibia and femur can be bridged successfully and bone be maintained by the use of apposing massive bone grafts. This conclusion is the proved integrity of the autogenous massive bone graft [4] and on the fact that m grafts, when placed in apposition at the site of a defect, become integral parts of e other as well as of the host bone itself. When these grafts are obtained from the affected bone, the complications associated with the removal of massive donor grafts from the opposite tibia are avoided, and normal functional use of the sound extremity is maintained. With the use of supplemental bone from the ilium, defects too great to be repaired by the use of apposing massive grafts can be reconstructed successfully by the use of a single stabilizing massive graft from the same bone, augmented by apposing iliac chips or blocks. Likewise, residual donor defects become regenerated more rapidly and completely when filled with iliac bone.

In the treatment of compound fractures of the tibia and femur in combat casualties, one of the most difficult problems encountered was non-union with loss of bone substance [6]. In order to bridge these defects in accordance with the basic principle of maintaining bone length, the technical operative procedures described here were developed. Their purpose is reconstruction of the normal architecture of tubular bone at the site of the defect by the use of apposing massive grafts. Each graft comprises one-half the circumference of the affected bone,—the so-called half-cylinder grafts described by Hey Groves. The defect is bridged with external surrounding cortex in the form of a complete cylinder, and continuity of the medullary canal is re-established.

SURGICAL PROCEDURE

Three distinct operative procedures have been developed for the tibia and femur, according to the level of the defect (Figs. 1-A, 1-B, and 1-C). The operative approach to the tibia is routine, and varies according to the presence and location of cicatricial tissue. The approach to the femur is through the standard anterolateral incision. The shaft of the affected bone is exposed subperiosteally above and below the defect, and dissection is continued to the site of non-union. All scar tissue that can possibly be removed is excised. The bone ends are freed and all poorly nourished bone is removed back to normal bone, the bone ends being squared by means of a hand saw. The defect, with longitudinal traction applied, is measured, and the pattern and length of bone grafts are determined. All grafts are removed subperiosteally, care being taken to allow periosteum and muscle attachments on the sound portions of the shaft to remain attached. The grafts are removed in the following manner: Longitudinal cuts of the superficial cortex are made with a motor saw. Crosscuts are made with drill holes and a narrow osteotome. Care is taken to complete the crosscuts before the deep cortex is cut through longitudinally; otherwise there is danger of splitting the shaft of the bone through to the adjacent joint, or of breaking through the sound portion of the bone at the level of the crosscut. The deep cortex is cut from the site of the defect toward the crosscuts by means of osteotomes and a mallet, after multiple drill holes have been placed along the plane of the desired cut in

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

particularly in the femur, where the portion of the extremity distal to the fracture site is heavy and is under the control of an assistant during the manipulation necessary for reduction.

CONCLUSIONS

Apposing massive half-cylinder grafts, when firmly fixed, become integral parts of each other as well as of the host bone.

By reconstruction of the tubular architecture of the bone at the site of the defect, with supporting external cortex in the form of a cylinder and re-establishment of continuity of the medullary canal, solid union can be accomplished and tubular strength can be regained.

Complications associated with the removal of massive grafts from the unaffected tibia are avoided by this method, and unrestricted use of the sound extremity is possible.

The use of iliac bone to facilitate new-bone formation in residual donor defects is practical in the tibia; but does not seem indicated in reconstruction of the femur, because of the unusually abundant blood supply of this bone. Iliac bone, in the form of blocks or chips, is an excellent medium of osteogenesis for bridging bone defects in cases in which the original defect is too great to be repaired by apposing massive grafts from the affected bone. Emphasis is placed on the use of supplemental iliac bone in the bridging of defects only where rigid stabilization of the bone fragments is maintained by a single half-cylinder graft as a bed for the apposing iliac bone.

Preoperative reconditioning of the patient and of the affected extremity is considered to be equally as important in the final outcome as the reconstruction surgery itself.

These procedures seem applicable not only in the presence of large defects, but also in cases of non-union of the tibia and femur with small defects, caused by the interposition of fibrous tissue and sclerotic bone ends. In such cases, if the interposing fibrous tissue and sclerotic bone ends are removed, some shortening must result in bringing the bone ends into contact. This requires osteotomy of the fibula when the non-union is in the tibia. If the interposing fibrous tissue and sclerotic bone ends are not removed, the integrity of union must depend upon the onlay or inlay bone grafts. In these latter cases, bone-bridging develops only at the site of the graft. Refracture frequently occurs through this site of faulty union.

The length of the tibia or femur is the most important factor in determining the maximum length of defect which can be bridged by apposing half-cylinder grafts from the same bone. In the authors' experience, it was possible to bridge bone defects, ranging up to two and one-half inches in length, with apposing massive grafts. In defects greater than this, use of a single half-cylinder sliding graft and filling in of the opposite half of the defect with a block of iliac bone or with iliac-bone chips is advocated.

In the final analysis, successful bridging of defects with massive bone grafts depends on an adequate blood supply to the grafts and positive fixation of the grafts internally. By separation of the periosteum only at the site of the bone grafts to be removed, with the periosteum and muscle attachments left undisturbed on the sound portions of the shaft, an adequate blood supply is maintained for the successful revascularization of the grafts.

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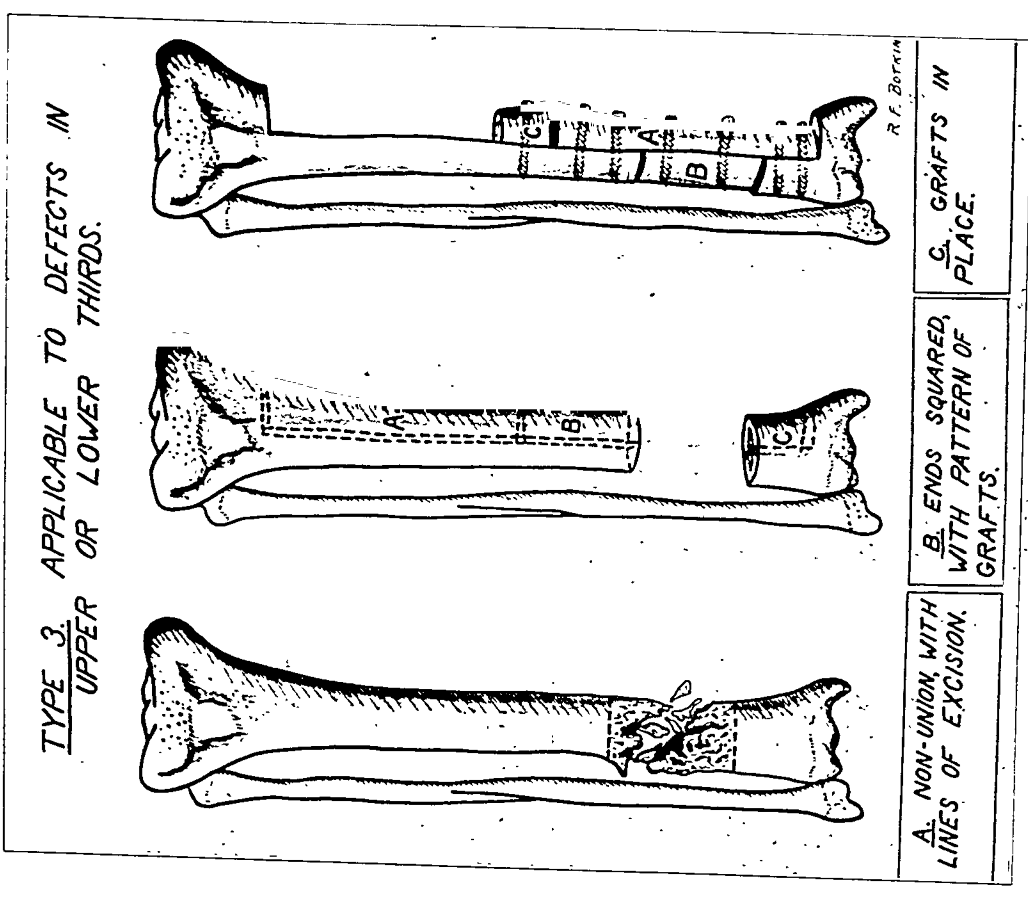

Fig. 1-C
Type 3 procedure.

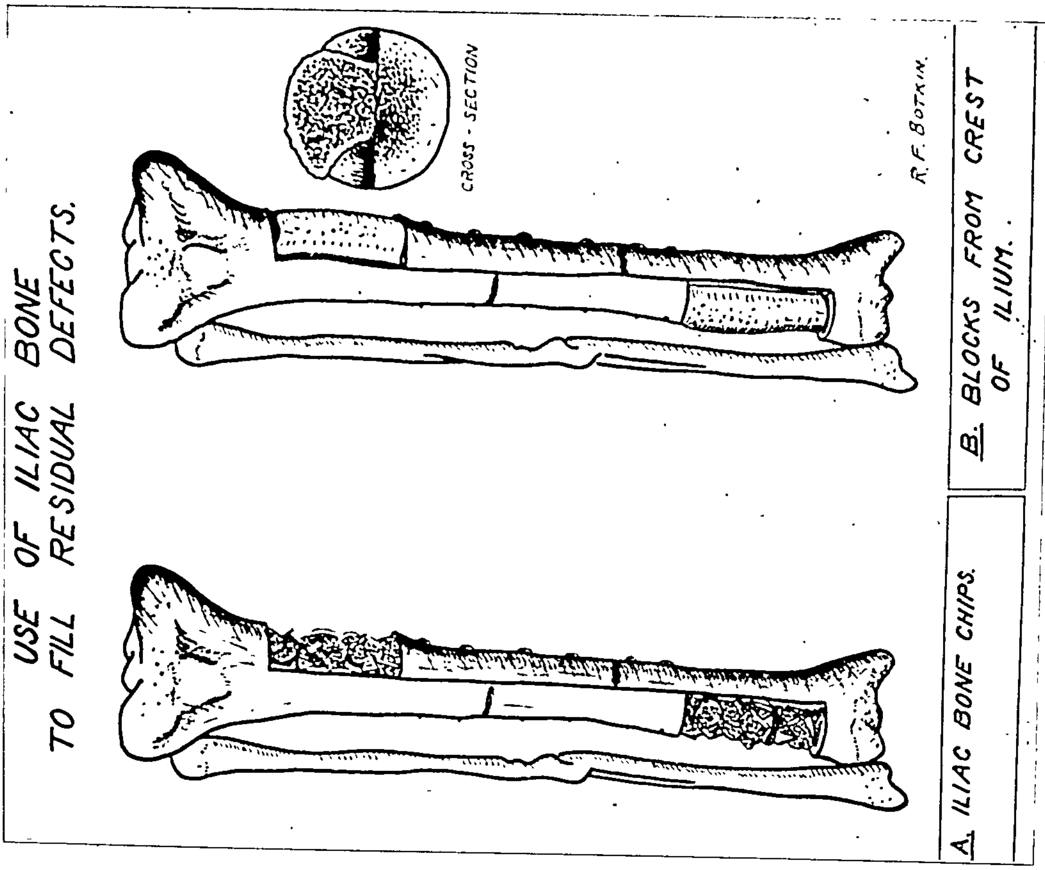

Fig. 1-D
Procedure for use of iliac bone.

CALCIFIED MEDULLARY DEFECTS IN BONE

BY ALBERT BARNETT FERGUSON, JR., M.D., BOSTON, MASSACHUSETTS

From the Surgical Clinic of the Peter Bent Brigham Hospital, Boston

The presence of a symptomless, solitary, rounded mass of irregular nodules of amorphous calcification within the medullary cavity of a long bone has been mentioned, but not adequately described, in the medical literature. Such lesions, incidentally noted during the roentgenographic examination of the neighboring joint, are sometimes confusing, and clarification of their clinical and roentgenographic features is needed.

ROENTGENOGRAPHIC APPEARANCE

Calcified medullary defects of bone appear as solitary, rounded areas, made up of irregular nodules of amorphous calcification, in or near the metaphyseal regions of the long bones. They are frequently located in the center of the medullary cavity and are of variable size,—usually one to two centimeters in diameter. When these areas are larger, they are likely to be confused with caisson disease in bone. The nodules are of even calcific density. The periphery of the lesion reticulates with the normal bone lines, but is sharply demarcated from normal bone structure. There is no central area of lesser density and no shell of calcification. There is no expansion of the shaft of the bone, and lesions do not extend into the cortex. This combination of positive and negative features is typical of calcified medullary defects, and differentiates them from other bone lesions of somewhat similar appearance. Figure 1 shows a typical lesion in the lower portion of the femur, while Figure 2 is a lateral roentgenogram from another case, showing a somewhat larger lesion A calcified medullary defect located in the greater trochanter is shown in Figure 3. So little disturbance of medullary structure is produced that, apparently, these lesions are visible

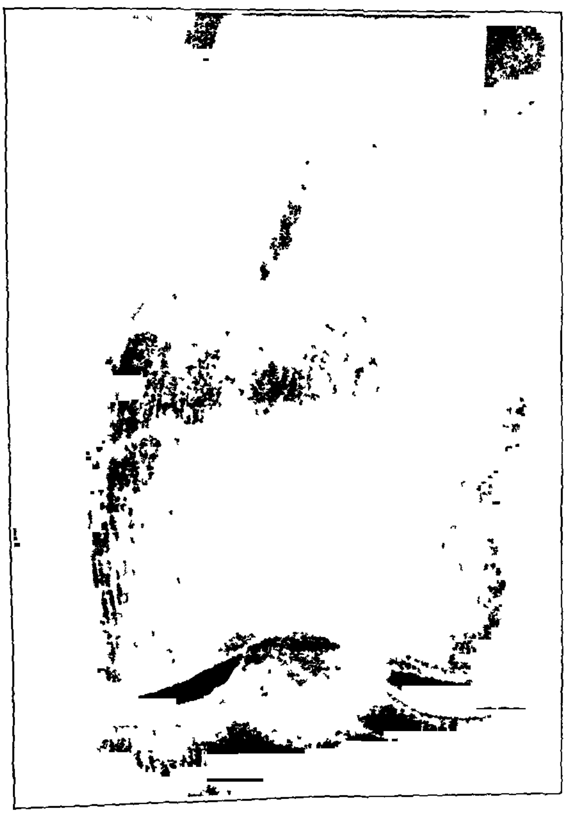

FIG. 1

FIG. 2

such surgery is undertaken. Bone surgery should not be performed in less than three months after the compound wound has completely healed and after all obstructing cicatricial deformities have been eliminated.

Penicillin is used routinely, except in cases in which the original invading bacteria are penicillin-resistant. In these cases, sulfonamide therapy is used[5]. In cases where large soft-tissue and bone defects were treated by early saucerization and split-thickness skin-grafting[3], bone surgery should not be instituted for a period of three months after replacement of these thin grafts with full-thickness skin grafts, by means of either pedicle or tube grafts or by local skin flaps[1]. Considerable emphasis is placed upon physical reconditioning of the patient and of the involved extremity prior to reconstruction surgery. Patients with physical debility are treated with transfusions of whole blood, diets high in calories and proteins, and supervised graduated exercises. Following the healing of the compound wound, the plaster immobilization is removed and a supporting brace is applied to the affected extremity. Intensive physical and occupational therapy are utilized before operation for the purpose of mobilizing the adjacent joints, improving circulation and muscle tone, and improving the physiology of the affected bone. Motion at the site of non-union is not harmful, inasmuch as the bone ends are embedded deeply in dense fibrous tissue.

CASE REPORTS

CASE 1. A private, twenty-three years old, was admitted on July 19, 1943. He had a draining compound wound and loss of bone substance, involving the middle third of the right tibia, in addition to other injuries, as a result of a mine explosion by enemy action in Tunisia on April 21, 1943. Apposing massive bone-graft reconstruction was performed on December 15, 1943. At operation, a scar which involved the skin was excised in the line of incision; medial and lateral counterincisions were required for closure of the operative wound. A small portion of the operative incision failed to heal by first intention, which resulted in a localized low-grade infection at the site of one of the screws. *Staphylococcus aureus* was obtained on culture. Union of the bone progressed normally and weight-bearing in a supporting brace was permitted on June 1, 1944. Following excision of the metal plate and screws and of a small sequestrum, on November 22, 1944, the wound healed by first intention. The patient was discharged on April 26, 1945. The length of the defect bridged by apposing grafts was two and one-half inches. Residual shortening of the affected tibia amounted to one-half inch.

CASE 2. J. S., a captain, twenty-four years old, was admitted on February 21, 1944, twenty-four hours after a plane crash. In the accident he had sustained a compound fracture of the middle third of the left tibia with loss of bone substance, in addition to other injuries. The wound was debrided and closed primarily; and distraction pins were inserted through the upper and lower ends of the tibia and incorporated into a circular plaster in order to maintain bone length. The compound wound healed by first intention (Fig. 2-A). An apposing massive bone-graft procedure was performed on September 15, 1944. Weight-bearing was permitted on December 8, in a supporting walking plaster. A supporting brace was applied on March 10, 1945, at which time union was completely solid (Fig. 2-B). The brace was removed on August 1, 1945. The length of the defect bridged was one and one-eighth inches. Residual shortening of the affected tibia measured three-eighths of an inch.

FIG. 2-C

Anteroposterior and lateral views, fifteen and one-half months after operation.

CASE 3. A private, thirty-seven years old,

Chondrodysplasia: Since medullary defects are felt to be a form of faulty development of bone from cartilage, such lesions may properly be classed under this broad heading. Occasionally, calcified bone defects are noted in conjunction with the typical familial type of chondrodysplasia with characteristic expansion of the shaft in multiple and symmetrical locations.

Osteoid Osteoma: These lesions may, occasionally, have a superficial resemblance to calcified medullary defects. In these cases, the osteoma is highly ossified and is located in the metaphyseal region,—a rare location for it. In the center of the dense sclerosis the lesion contains an area of translucency, which is not seen in the developmental defects. The pain and tenderness, which are associated with this lesion, help in its differentiation.

Sclerosing Osteogenic Sarcoma: There is definite pain, often quite severe, with this lesion Instead of being sharply demarcated by roentgenogram, the lesion characteristically fades away into the normal bone structure, often with cortical invasion. Occasionally in the early stages of this disease, particularly when it involves the proximal portion of the tibia, the resemblance to calcified medullary defects of bone may be marked. The sarcoma, however, will be found abutting on the cortex somewhere along its periphery. This aids in its diagnosis.

Osteoplastic Prostatic Metastases: Pain is frequent in these lesions, but they may be confused with developmental medullary defects. The history and physical examination may be significant. These lesions are usually multiple, more widespread, characteristically in the pelvis, and usually are not so dense as calcified medullary defects. When multiple, their tendency toward a circular, rather than a rounded, nodular structure is evident. There may be loss of normal bone structure surrounding the lesion, and the density is extremely variable. Osteolytic lesions may be noted in conjunction with osteoplastic metastases.

Bone Infarcts: As described in the literature[2], these lesions have a distribution similar to calcified medullary defects and are similar to caisson disease, although an occupational history may not be obtained. Roentgenographically, these lesions may appear to involve

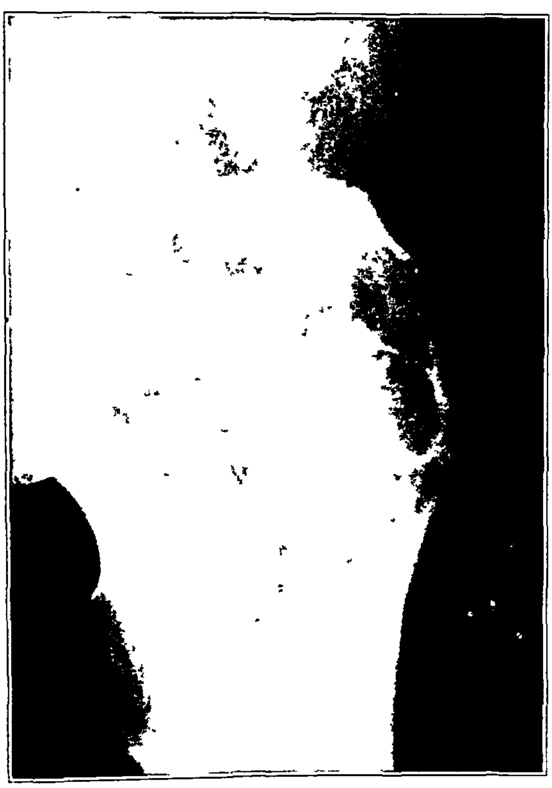

Fig. 3

Fig. 4-A

Fig. 4-A: Calcified defect removed intact at open reduction of accompanying fracture.

length of the defect bridged was two and one-half inches. Residual shortening of the right lower extremity amounted to five-eighths of an inch.

CASE 7. A private, twenty-two years old, was admitted on April 4, 1945. He had a healed compound wound of the left leg, and non-union associated with a bone defect involving the lower third of the left tibia, as a result of a severe shell-fragment wound incurred during enemy action in Sicily, July 16, 1943. Two

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 8, F. B. Bone defect before operation.

Fig. 4-B: Roentgenograms taken during the operation show the steps of the Type 3 procedure with squaring of bone ends, removing massive half-cylinder grafts, rebedding grafts across defect, and filling residual donor defects with iliac chips.

FIG. 4-C

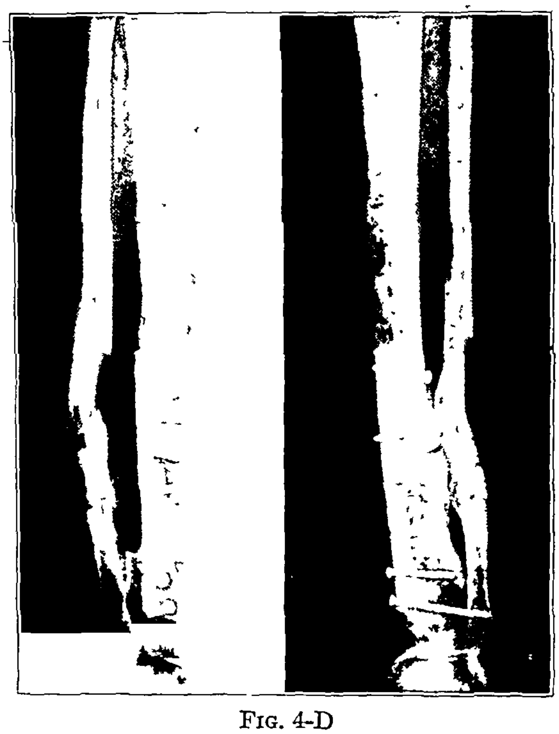

FIG. 4-D

Fig. 4-C: Anteroposterior and lateral views, three months after the operation.

Fig. 4-D: Anteroposterior and lateral views, six months after the operation.

CASE REPORT

Through the courtesy of Carl W. Walter, M.D., it was possible to procure a section of a calcifying developmental defect for biopsy. This lesion was noted incidental to a spiral fracture of the distal third of the right femur.

T. F., a white male, sixty-eight years old, a stationary engineer, never engaged in construction work, entered the Peter Bent Brigham Hospital with a spiral fracture of the middle and distal thirds of the right femur, following a fall on getting out of bed. A calcified developmental defect was found in the distal section of the fractured bone. Figure 4-A, taken on admission, shows this lesion with the associated fracture.

At open reduction, this calcified area was removed, apparently intact and easily separated from the adjacent bone, leaving a round defect where it had been nesting. Postoperative roentgenograms revealed that the lesion had been removed except for two small flecks of calcification. The lesion consisted of reddish tissue, irregularly shaped into a rounded mass, approximately one centimeter in diameter and two centimeters in length, and containing hard yellow areas. It was found to be glassy hard and rang when dropped on a hard surface.

Sections revealed a somewhat irregular area of calcified, non-viable cartilage, at the periphery of which a slow process of new-bone formation was taking place. Figure 4-B is a low-power photomicrograph taken at the periphery of this lesion. It shows all features of the lesion, from calcified cartilaginous matrix on the left to bone spicules with small attached areas of viable cartilage on the right. A high-power photomicrograph of the cartilaginous matrix with an area of viable cartilage is shown in Figure 4-C.

DISCUSSION

There is no evidence that this lesion is expansile or has any power of autonomous growth, and it cannot be classed as an enchondroma. Its location is in keeping with other cartilaginous disturbances of bone formation; and, as an example of faulty development of bone from cartilage, it may be classified as one of the many forms of chondrodysplasia.

The pathological and clinical findings lead one to the conclusion that this lesion is a degenerated calcified island of cartilage, which did not progress to complete ossification at the time of skeletal growth.

The solitary, non-symmetrical nature of this lesion supports the contention that trauma may be an etiological factor. Rickets may also be mentioned in connection with this lesion.

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FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 14, T. C. Bone defect before operation.

Fig. 5-B: Roentgenograms taken during the operation show the Type 2 procedure with the steps of squaring of bone ends, removal of massive half-cylinder grafts, rebedding of grafts across defect, and filling residual donor defects with iliac bone chips.

FIG. 5-C

FIG. 5-D

Fig. 5-C: Anteroposterior and lateral roentgenograms, ten weeks after the operation.

Fig. 5-D: Anteroposterior and lateral roentgenograms, five months after the operation. The length of the defect bridged was one and five-eighths inches.

For instance, it is useless to attempt arthrodesis of the upper extremity in an adult by using a graft. The primary objectives are to cure the lesions and, at the same time, to preserve as much as possible the mobility of the joint. Both of these ends can be obtained by resection.

For joints of the lower limb, there are hardly any indications for arthrodesis by grafting, except in the hip. Resection of the knee gives excellent results. Of course, after a certain age, resection can no longer be done, because fusion would not be good; but in these cases, bone grafts have little better chance of a successful outcome. In the ankle joint and in the tarsus, resection is the better procedure, although the results are often uncertain.

In the final analysis, it would seem that the use of bone grafts in the treatment of tuberculosis of the joints has been overdone in recent years; and we are forced to admit that their use should be limited.

There still remains a wide field for the bone graft,—namely, in the two most frequent and most serious adult tuberculous affections: Pott's disease and disease of the hip joint. In fact, before the use of the bone graft, no successful operative treatment for these conditions was available. Resection of the hip, although easily performed, gave unfavorable results; and in tuberculosis of the spine, direct operations on the focus of infection seemed inconceivable.

Non-operative treatment gave deceptive results in both affections among adults, so that until about 1920, hip disease and Pott's disease were considered very serious, and in both cases the prognosis was grave. The use of bone grafts certainly brightened the picture. The large number of cases operated upon, as well as the length of time which has passed since operation, enables us to recommend the measure.

In tuberculosis of the spine, bone grafts have been done most frequently and over the longest period of time. The writer has practised this procedure for twenty-six years; and, although the exact number of cases is unavailable, it must be close to 500.

Precautions should be taken both before and after the operation. We think it inadvisable to operate upon a patient at the onset of Pott's disease, when the disease is actively developing and showing disquieting general phenomena with fever, loss of weight, and intense pain, or when an abscess or a paraplegia has recently appeared. It is better to wait until the lesions are stabilized and until the patient has in some way given proof of his capacity to withstand the disease. In fact, it is often well to immobilize the patient before operation, and to recommend rest in the mountains or at the seashore.

After the operation has been performed, the patient should be immobilized for about six months, because the bone graft must have sufficient time to become solidly fused with the spinous processes, so that it can play the role expected of it. Walking should be started very gradually, and the patient should wear a plaster jacket.

The belief that a cure of Pott's disease may be obtained by placing of a bone graft early in the disease, and then allowing the patient to resume normal life after some weeks in bed, is unfounded. This mistake was made when the method was first used; but, because the results were so uncertain, the use of the graft was abandoned. However, during the past two decades, since we have realized the importance of exercising great care, grafts have been used more and more. Proceeding in this prudent way, associating surgical with general treatment, we have obtained excellent results in Pott's disease in adults. Cures are usually stable and definitive, and the patients are able to take up a really active life once again without any reappearance of the disease, contrary to our experience with non-operative methods. We have seen, for instance, a great number of women undergo completely normal pregnancies after such an operation, and this would seem to be a demonstrative proof.

An important question arises as to the age at which these grafts can best be used. As we have said, there are few indications among children. It is only when the child becomes an adolescent, and when fusion of the diseased vertebrae fails, that grafts should be uti-

5. Mech, K. F.: Wound-Healing in Compound Fractures and Repair of Bone Defects. J. Bone and Joint Surg., **26**: 442–447, July 1944.
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7. Physical Reconditioning. War Department Technical Manual, TM 8-292. Washington, U. S. Government Printing Office, 1944.

DISCUSSION

Dr. James A. Dickson, Cleveland, Ohio: Major Flanagan and Captain Burem have made a real contribution to bone surgery and have demonstrated what can be accomplished by a well-planned and expertly executed procedure in bridging bone defects.

One might be a little skeptical about the end results following such extensive surgery in the involved bone, but the solid bony union with re-establishment of contour of the shaft of the bone and the consistently excellent results are striking and convincing testimony that their principles are sound. They have developed a very ingenious method of freeing the grafts from the host without interfering with the periosteum and the blood supply of the remaining portion of the bone, which principle, I am sure, plays an important role in their success.

In the last analysis, they are making use of the best features of the dual graft without interfering with the good leg, which, we must admit, has definite advantages.

After World War I, many attempts to bridge bone defects were carried out along the lines suggested by Hey Groves; but, due to the lack of suitable metal screws, the results were disappointing in many instances. Now that we have Vitallium screws to assure positive internal fixation, and chemotherapy, together with this method of preserving a good blood supply in the host fragment, excellent results are the rule rather than the exception, as Major Flanagan and Captain Burem have so ably demonstrated.

I certainly agree with them that the preoperative reconditioning of the patient and of the affected extremity is most important, and I am sure this played no small part in the excellent results they obtained.

It has been a great pleasure indeed to have had the opportunity of discussing their paper, and I feel that Major Flanagan and Captain Burem have demonstrated the application of very sound principles and are to be congratulated on their excellent piece of work.

mobilization, under the protection of which it is safe to allow the patient to resume walking gradually. As time passes, the graft strengthens. Roentgenograms of grafts taken some years after their application always astonish physicians, who have hitherto been adherents of the old classic dicta that grafts live only with difficulty and have a tendency to be absorbed.

After hip disease has run its course, grafts can still render great service by fixing the hip in good position, enabling the patient to walk better, and preventing reactivation of the infection. It is a reconstructive operation, devised for cured lesions. Above all, it is indicated for children, in whom one sees great destruction of bone. The extra-articular graft placed as a bridge from the ilium to the trochanter would break or tear its insertions during growth; so we must have recourse to a different procedure. For a long time we have combined an intra-articular and extra-articular arthrodesis, which we have called mixed arthrodesis. After having opened wide the joint, we scrape the articular surfaces. Then, with a graft taken from the wall of the ilium or from the tibia, we join at the same time the cotyloid rim, the head, and the neck of the femur to the level of the greater trochanter. Thus is formed a solid bony block, and the growth of the femur is not hindered.

In conclusion, it seems to us that, among adolescents, adults, and aged people, immobilization grafts have been of great help in the treatment of tuberculosis of the joints; and in two of its most frequent and most severe localizations, in the spine and the hip, end results have been greatly improved by bone grafts. Among children, the use of grafts has brought only slight modifications in the treatment of Pott's disease and tuberculosis of the joints. However, in the sequelae of hip disease these immobilization grafts have been found to be extremely useful.

TABLE I

DISTRIBUTION OF NON-OSSEOUS DEFECTS

	Number of Patients	Per Cent.
Distal portion of femur	25	59.5
Proximal portion of tibia	6	14.3
Proximal portion of femur	3	7.1
Proximal portion of humerus	3	7.1
Wing of ilium	2	4.8
Patella	1	2.4
Proximal portion of fibula	1	2.4
Vertebra	1	2.4
Total	42	100 0

only after they have become calcified. This is in contradistinction to lesions such as Schmorl's nodes.

DISTRIBUTION

Histories and roentgenograms of cases noted in private practice were secured through the courtesy of Louis G. Howard, M.D. Statistics on the distribution of calcified medullary defects were secured from an additional thirty-one cases. A total of forty-two cases were examined roentgenographically, and the distribution of these lesions is summarized in Table I. Their predilection for areas where skeletal growth is greatest was noted, with the distal portion of the femur the site of 59.5 per cent. of the lesions.

Typically, these lesions are solitary; but in one case, when the wing of the ilium was involved, the occurrence was bilateral; and in another case a lesion was found both in the wing of the ilium and in the neck of the femur.

CLINICAL DESCRIPTION

None of these patients complained of pain that could be ascribed to the area occupied by the calcific bone mass. All the patients were in the age group of forty years and over, with the exception of a veteran, aged twenty-four.

Three of these patients were subjected to a clinical and roentgenographic follow-up of from six months to two years. In that period they remained symptomless, and no changes in the roentgenographic appearance occurred.

In all cases the lesions were found during the search for pathological changes in the neighboring joint. These pathological changes ran the gamut of orthopaedic conditions and included such lesions as tuberculosis, coxa plana, and degenerative arthritis.

DIFFERENTIAL DIAGNOSIS

The fact that this lesion is symptomless helps to distinguish it from the following diseases in which other pathological changes are involved:

Caisson Disease of Bone: The occupational history and the presence of some pain are characteristics of this condition. Roentgenographically, the lesion is not uniformly dense, but appears as irregular areas of translucency and will frequently be found in conjunction with arthritis of the neighboring joint. A thin band of calcification surrounding the area is not uncommon.[1] This was not seen in cases of calcified medullary defects. The distribution of the lesions in caisson disease is often multiple rather than solitary, and may involve the mid-shaft of the bone. As a rule, the bone involvement is much more extensive than that of the calcified non-osseous defects.

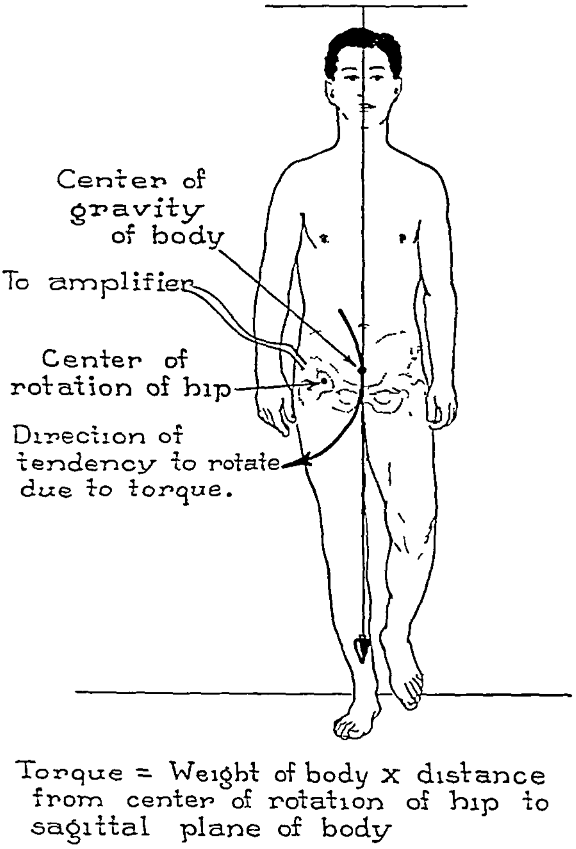

FIG. 1

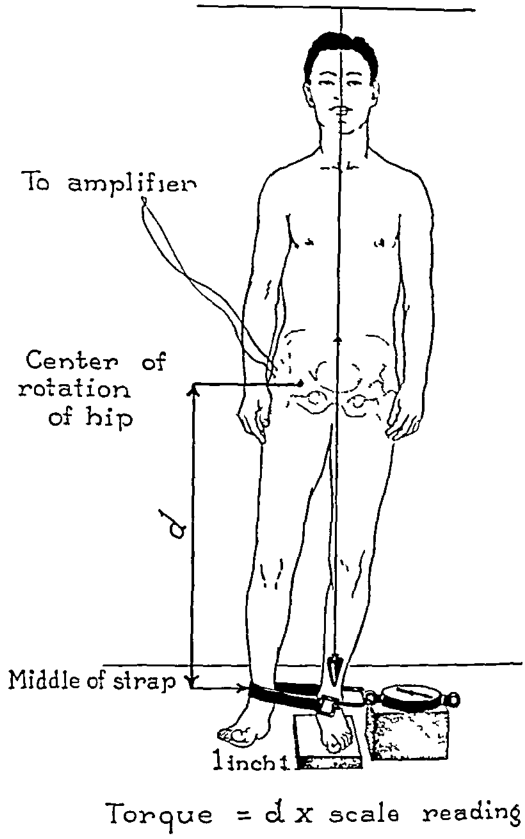

FIG. 2

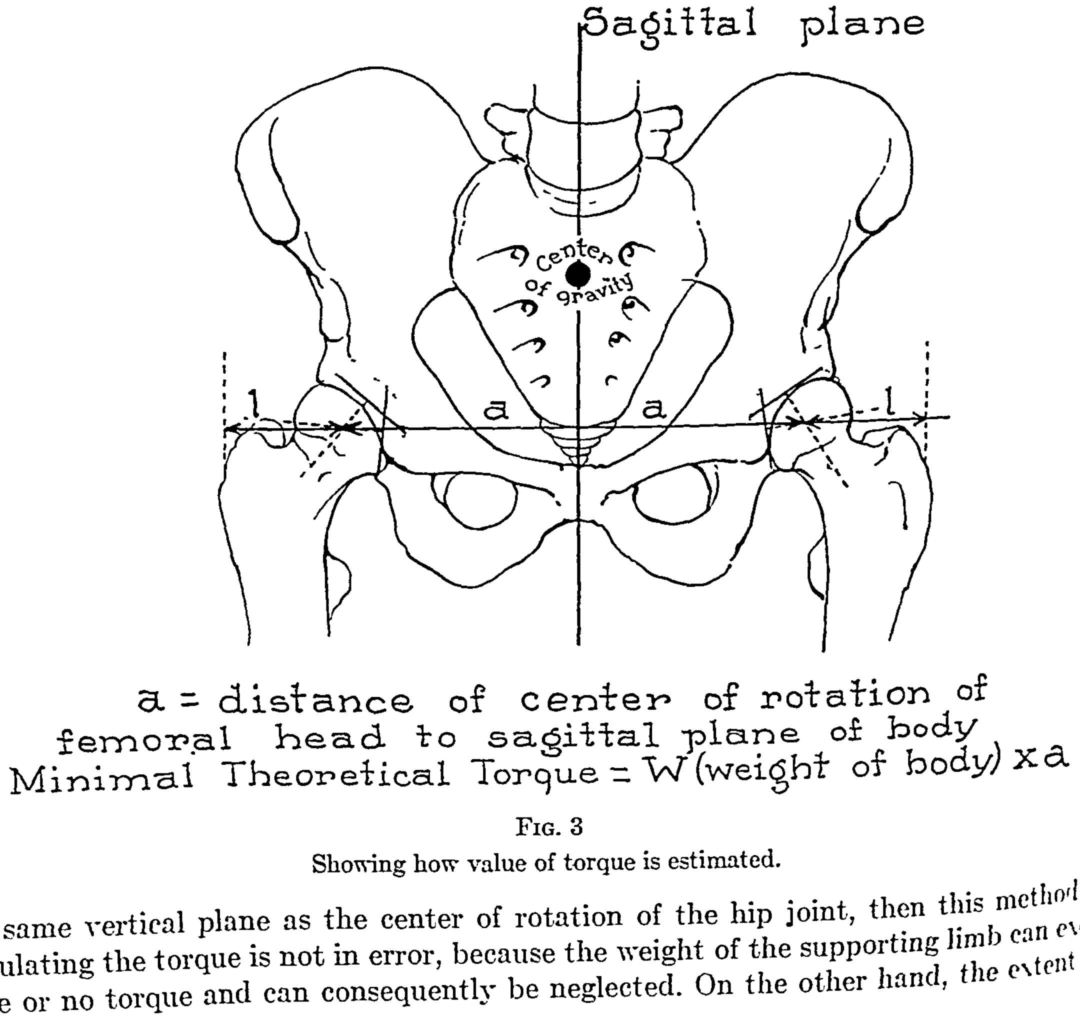

FIG. 3
Showing how value of torque is estimated.

the same vertical plane as the center of rotation of the hip joint, then this method of calculating the torque is not in error, because the weight of the supporting limb can exert little or no torque and can consequently be neglected. On the other hand, the extent to

articular cortex They contain cystic areas of translucency and often are surrounded by a thin wall of calcification. Their density is not even. There is often an associated arthritis.

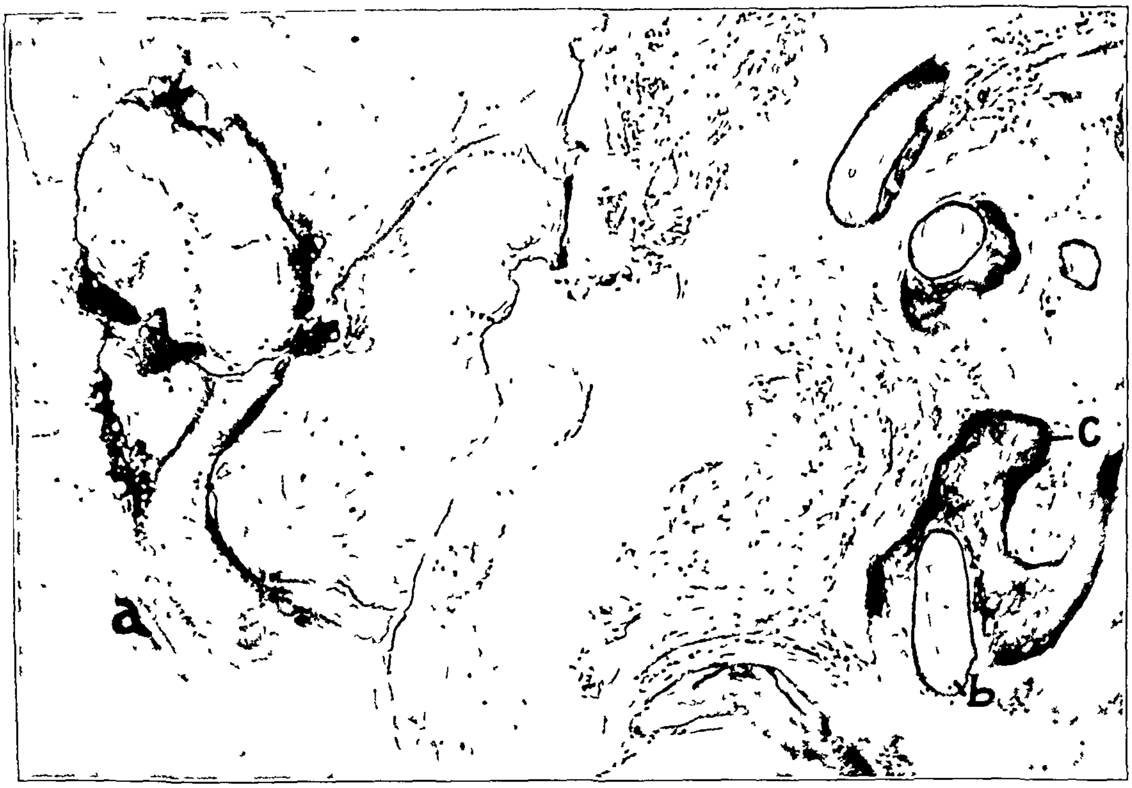

Fig 4-B

Low-power photomicrograph taken at the periphery of the lesion *a* indicates calcified cartilaginous matrix, *b*, bone spicule, *c*, attached area of viable cartilage.

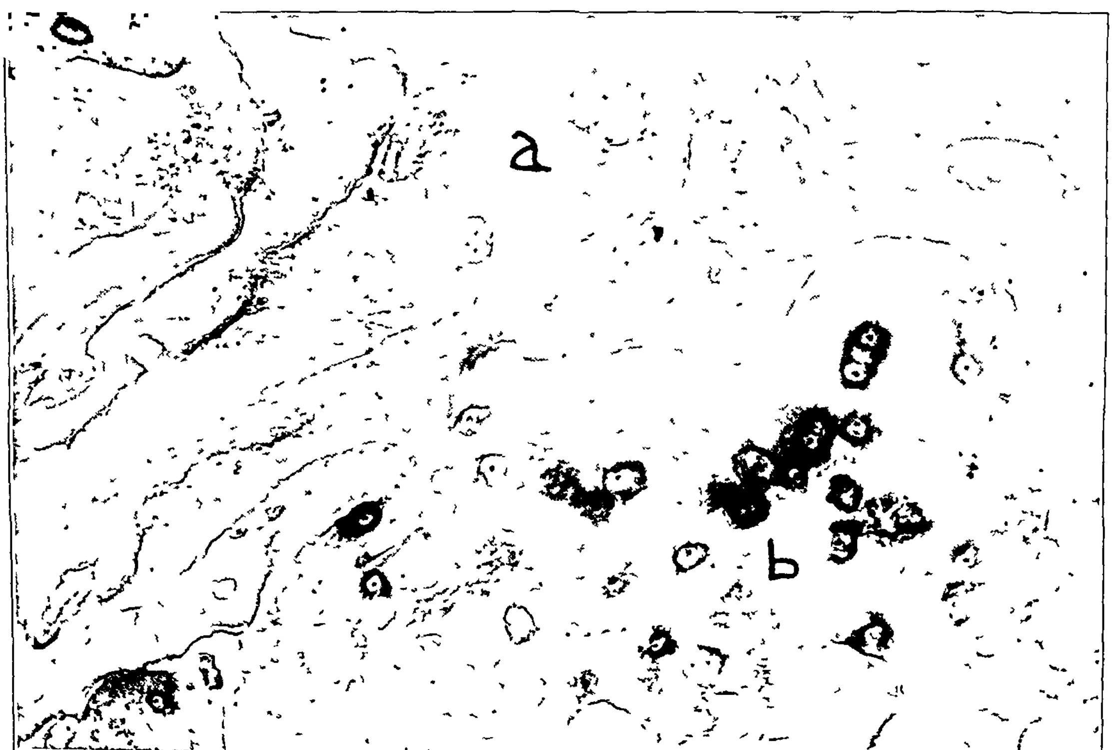

Fig. 4-C

High-power photomicrograph from the center of the lesion. *a*, cartilaginous matrix; *b*, area of viable cartilage.

Without disturbing the position of the electrodes or the settings of the amplifiers, and without grossly altering the position of the subject, the weight was transferred to the opposite limb. A small block was placed under the foot so that the extremity from which the recordings were taken just cleared the floor without the necessity of flexing either the hip or the knee. The distance between the heels of the two feet was kept at less than five inches. Around the ankle at the level of the lateral malleolus was placed a strap, to which was fastened a spring scale whose excursion was very small. The elongation of the spring was less than one centimeter when the scale registered from zero to fifty kilograms. The location of the femoral head was marked on the anterior aspect of the groin, as determined by palpation of the femoral artery just distal to the inguinal ligament. The distance from the femoral head to the middle of the strap about the ankle was measured in centimeters. The power of abduction could be measured accurately and expressed as a rotatory force in kilogram-centimeters by multiplying the distance from the center of rotation of the femoral head to the leather strap by the reading on the spring scale (Fig. 2). Simultaneously, the action potential of the contracting abductors could be recorded. From four to eight loci were plotted from zero to the maximum power of abduction, and were connected by means of a smooth curve. From the graph could be obtained the value of the torque at any known action potential. The action potentials of the abductor muscles of the hip, when the patient was bearing weight upon one lower extremity, could be translated directly into moments of force (torque). From the graphs of each subject (Fig. 4), the experimental torque so obtained could be compared with the theoretical torque determined previously.

The values for experimental torque, taken with the pelvis level, were consistently lower than the calculated values for theoretical torque. The disparity between the two

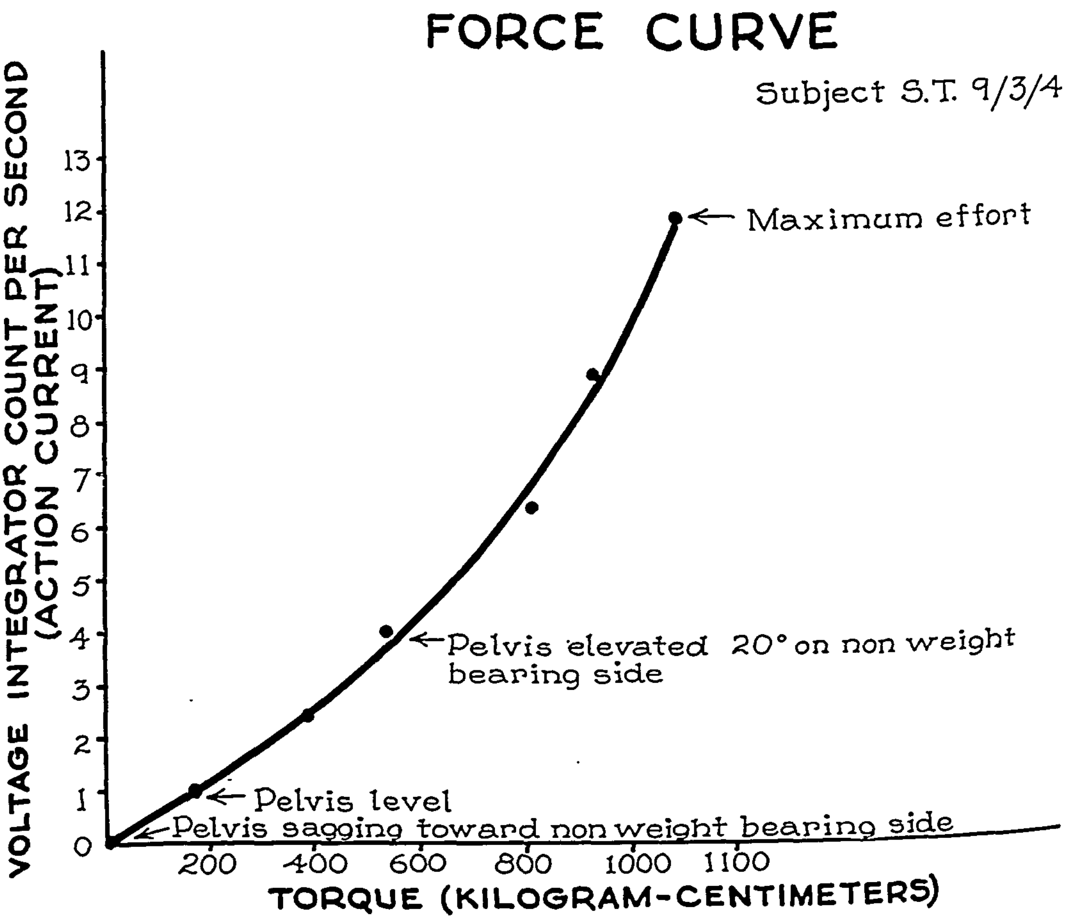

FIG. 4

A typical force curve, relating torque to action potential of abductor muscles.

IMMOBILIZATION WITH BONE GRAFTS IN THE TREATMENT OF TUBERCULOSIS OF THE JOINTS AND POTT'S DISEASE *

BY PROFESSOR ETIENNE SORREL AND MADAME SORREL-DEJERINE, PARIS, FRANCE

In 1920, when the use of bone grafts for immobilization in the treatment of Pott's disease was first begun in France, the method was new to us and untried. Although Albee had already performed the operation in the United States, and his technique had been fully described, his operative method had been severely criticized. Favorable results did not seem to follow the few trials made in France before 1914; and, during the long years of World War I, interest in the perfection of the technique, of necessity, waned. However, after 1918, interest in bone grafts was revived, and a great deal of study was devoted to their successful use.

From the first, it was realized that fixation of the diseased vertebrae by a bone graft, although not universally applicable to all cases of Pott's disease, would give excellent results under certain well-defined conditions. By analogy, the same method could be applied in treating tuberculosis of the other joints. Some good results ensued; in other cases, however, the results were not so good as those obtainable by methods already in use.

In short, in this paper, the writer is attempting to sum up from his own long experience the progress which has attended bone-grafting in the treatment of joint tuberculosis over the years.

Fixation by bone graft certainly must not be performed routinely in all cases of joint tuberculosis. There are two reasons why it is only rarely indicated for children: first, because often cures may be effected, especially in young children, leaving them with good joint function and in better condition than if the joint had been blocked by a graft. In producing true bony ankylosis, two bare and ulcerated bones must be brought into direct contact. In children the epiphyses are for some years formed of a bony nucleus imbedded in cartilage, and such tissue is unfavorable ground for the development of tuberculosis. It frequently happens that with the passage of time the articular ends remain, if not intact, at least not completely destroyed; and some cartilaginous tissue remains to prevent bony fusion. On the other hand, in children suffering from Pott's disease, there often occurs a fusion of the diseased vertebrae, which results in a cure as definite as that brought about by the use of a graft.

The second and even more important reason why grafts are not often indicated for children concerns the growth of the skeleton. For example, to immobilize a knee joint, the bone graft must act as a bridge from femur to tibia over the epiphyseal cartilage. As the femur and the tibia grow, the bone graft, which does not stretch, may break or pull away from its points of insertion, or, if it holds, genu recurvatum, genu valgum, or genu varum may develop, conditions which are difficult to correct. The same situation holds true, not only for all bone grafts in the other articulations, but also for those in Pott's disease.

If shorter grafts are used which dovetail the two bony extremities, and pass through the epiphyseal cartilage, the results are even more unsatisfactory, for to the deformity of the limb there are added other problems of growth. In other words, success in the use of a graft can be looked for only when growth has almost ceased.

Further consideration of the possibilities for treatment of tuberculosis of the joint after growth has stopped leads to the conclusion that measures other than bone grafts are often satisfactory without being harder on the patient or more difficult for the surgeon. Except in a few special cases, it seems unnecessary to substitute immobilizing grafts for other treatment.

* Read at the Annual Meeting of The British Orthopaedic Association, London, October 18, 1946.

TABLE I

DETERMINATION OF TORQUE ABOUT THE HIP JOINT WITH PATIENT BEARING WEIGHT ON ONE EXTREMITY

Case No.	Patient	Age (*Years*)	Weight (*Kilograms*)	Torque (Kilogram-Centimeters)					A	B	C	D
					Experimental Values of Torque Obtained from Myographs							
				Calculated Torque (T)	Pelvis Sagging * (S)	Pelvis Level (L)	Pelvis Elevated * (E)	Maximum Effort (M)	$\frac{T-E}{T} \times 100$ (*Per Cent.*)	$\frac{E}{M} \times 100$ (*Per Cent.*)	$\frac{S}{E} \times 100$ (*Per Cent.*)	$\frac{L}{E} \times 100$ (*Per Cent.*)
MALES												
1	R. D.	51	59.8	562	49	175	523	1042	6.9	50.2	9.4	33.5
2	M. M.	29	69.5	690	36	252	672	1262	2.6	53.2	5.4	37.5
3	C. B.	34	82.0	732	96	650	855	1923	16.8	44.5	11.2	76.0
4	A. C.	27	62.5	670	70	274	612	1141	8.7	53.6	11.4	44.8
5	W. P.	26	76.2	700	0	685	746	1195	6.6	62.5	0	91.8
6	J. S.	43	83.0	905	206	629	990	1649	9.4	60.0	20.8	63.5
7	V. I.	38	80.0	780	38	232	718	1541	7.9	46.6	5.3	32.3
8	M. C.	22	69.2	620	45	375	600	975	3.2	61.5	7.5	62.5
9	J. E.	25	84.0	880	188	458	830	1352	5.7	61.4	22.6	55.2
10	J. C.	23	78.5	760	75	466	714	2040	6.1	35.0	10.5	65.3
11	P. D.	29	89.1	856	94	529	773	1319	9.7	58.6	12.2	68.4
12	W. M.	22	77.7	760	0	457	761	1423	0.1	53.5	0	60.1
13	A. M.	21	67.7	617	0	320	552	923	10.5	59.8	0	57.9
14	B. L.	23	74.9	692	0	144	648	1220	6.3	53.1	0	22.2
15	C. L.	22	77.1	771	0	340	620	1080	19.6	57.4	0	54.8
16	D. H.	50	66.4	624	19	296	558	890	10.5	62.7	3.4	53.0
17	S. L.	25	76.5	743	60	194	575	1008	22.6	57.0	10.4	33.7
18	R. I.	14	49.2	382	75	248	324	720	15.2	45.0	23.1	76.5
Averages									9.3	54.2	8.5	54.9
Standard deviation									± 5.7	± 7.3	± 7.4	±17.9

lized. Furthermore, they may be used until the patient has reached a fairly advanced age. One of our patients was fifty-eight when a graft was first applied for a very serious case of Pott's disease, localized in the thoracic region. This patient resumed active life a year later. After ten years he underwent prostatectomy. He is now seventy-eight years old, and is very well.

Another one of our patients, a physician, was sixty-three at the time the graft was applied for Pott's disease in the cervical region. This patient has remained perfectly well ever since.

Wherever Pott's disease may be localized—in the cervical, thoracic, or lumbar regions—the technique is about the same, differing only as there exists or does not exist a marked kyphosis.

If kyphosis exists, it is better to take a flexible graft from the tibia with the hammer and chisel. This graft will adapt itself better than the rigid graft to the curve of the kyphosis. If kyphosis does not exist, it has been found that the rigid graft, taken with the double electric saw from the tibia, according to the method of Albee, is the best. The over-all result is the same, and whether the graft is rigid or flexible, it provides complete immobilization.

For hip disease in adults, arthrodesis with the use of grafts has modified the formerly grim prognosis. We have operated upon a great number of patients with hip disease during its development; and, judging from the time which has elapsed since the first operation, we feel that the results may be called satisfactory.

In the report which we presented in London in 1933 at the Congress of the International Society of Orthopaedic Surgery, we pointed out that at that time we had already seen seventy-five of our old patients, twenty-nine of whom had been operated upon from two to six years previously. The number of patients operated upon has increased considerably. Thirteen years have passed, and the results have demonstrated the success of the operation.

As with Pott's disease, prudence must be exercised, and the patient should be operated upon only when the general and local conditions allow it. One of the most important lessons for the surgeon dealing with active hip disease is that of learning to wait before operating, while carrying out preliminary general treatment. After the operation, complete immobilization in plaster is necessary for a minimum of three months, and sometimes for six.

Arthrodesis with a graft for active hip disease cannot be done on young children for the reasons already mentioned, but can be employed from the thirteenth or fourteenth year to a fairly advanced age.

One of our patients was fifty and, although her hip disease was of a severe form, she could walk again three months after the operation, and is now, at sixty, very well.

Another patient was fifty-six. After being immobilized for three months, she took up active life. During a period of eight years, we continued to hear that she was well, but during the War we lost track of her.

Another patient fractured her graft in the course of a bad fall. This graft united very well. We have seen other similar examples which prove the viability of these grafts, and the confidence which one can have in them.

In cases where arthrodesis is performed during the progress of hip disease, a well-defined technique should be followed:

The graft should be placed at a certain distance from the diseased joint. We have found that the technique giving best results uses the extra-articular graft, which is taken with the electric saw from the tibia, and which is placed so as to unite the wall of the ilium and the trochanter by a fixed bony bridge.

Like the vertebral grafts in Pott's disease, these iliotrochanteric grafts in hip disease give admirable results. They fuse solidly at their extremities in the iliac wall and in the trochanter. They develop and grow larger. After some months, they result in absolute im-

TABLE I

DETERMINATION OF TORQUE ABOUT THE HIP JOINT WITH PATIENT BEARING WEIGHT ON ONE EXTREMITY

				Torque (Kilogram-Centimeters)					A	B	C	D
					Experimental Values of Torque Obtained from Myographs							
Case No.	Patient	Age (*Years*)	Weight (*Kilograms*)	Calculated Torque (T)	Pelvis Sagging * (S)	Pelvis Level (L)	Pelvis Elevated * (E)	Maximum Effort (M)	$\frac{T-E}{T} \times 100$ (*Per Cent.*)	$\frac{E}{M} \times 100$ (*Per Cent.*)	$\frac{S}{E} \times 100$ (*Per Cent.*)	$\frac{L}{E} \times 100$ (*Per Cent.*)
MALES												
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18	R. I.	14	49.2	382	75	248	324	720	15.2	45.0	23.1	76.5
Averages									9.3	51.2	8.5	51.9
Standard deviation									± 5.7	± 7.3	± 7.4	± 17.9

FUNCTIONAL ASPECTS OF THE ABDUCTOR MUSCLES OF THE HIP *

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INTRODUCTION

The glutaeus medius limp is characteristic and familiar to most physicians. To the orthopaedic surgeon it presents a problem which is easy to understand, but difficult to solve. To date no surgical procedure has been devised, either in the form of muscle transplantation or osteotomy, which will improve adequately the function of a hip deprived of its abductor muscles. In addition, a study of patients who have suffered paralysis of the abductor muscles in infancy discloses that the growth of the proximal end of the femur is altered on the involved side. The normal angulation of the femoral neck fails to develop, and coxa valga results.

Before any surgical procedure for the improvement of hip function can rest on an altogether sound physiological basis, or an explanation can be offered for the alterations in the growth of the femoral neck, a knowledge of the forces acting about the hip joint should be available. The most important forces appear to be those related to the pull of the abductor muscles, and further study of their function seems warranted.

Furthermore, a knowledge of the direction and magnitude of these forces greatly illuminates certain features, not only in the etiology of coxa valga, but also in that of malum coxae senilis, as well as pointing to the significance of the fascia lata and some of the effects of its shortening.

An attempt has been made to simplify this complex problem by considering it to be purely one of statics, and to discuss forces only in two dimensions. While it is realized that this is a three-dimension problem, only the static forces acting in the frontal plane of the body will be considered in this investigation.

It is apparent that the measurements of the forces developed by the abductor muscles in the living subject cannot be obtained directly, so that an indirect method must be employed. In this study, the method has consisted of the following steps:

1. Theoretical calculation has been made of the torque about the hip, when the subject is bearing weight on one extremity.
2. The value of the theoretical torque is checked experimentally.
3. When a determination has been made of the value of the torque which the abductor muscles must resist, the pull on the individual muscles and tendinous structures may be calculated.

THEORETICAL TORQUE ABOUT THE HIP JOINT

The minimum theoretical value of the torque about the hip, due to the center of gravity of the body being medial to the center of rotation of the hip joint when weight is borne on one extremity, is readily ascertained. Since the center of gravity necessarily lies in the median sagittal plane, the torque is the product of the body weight and the distance from the median sagittal plane to the center of rotation of the femoral he (Fig. 1). At first glance, it may appear that such an estimate of the torque is erroneo because the mass of the limb upon which the weight of the body is bein the level of the hip joint, and should be deducted from the weight of t however, the center of gravity of the supporting lower extremity can

* This investigation was made possible through a grant from the National Paralysis, Inc., New York, N. Y.

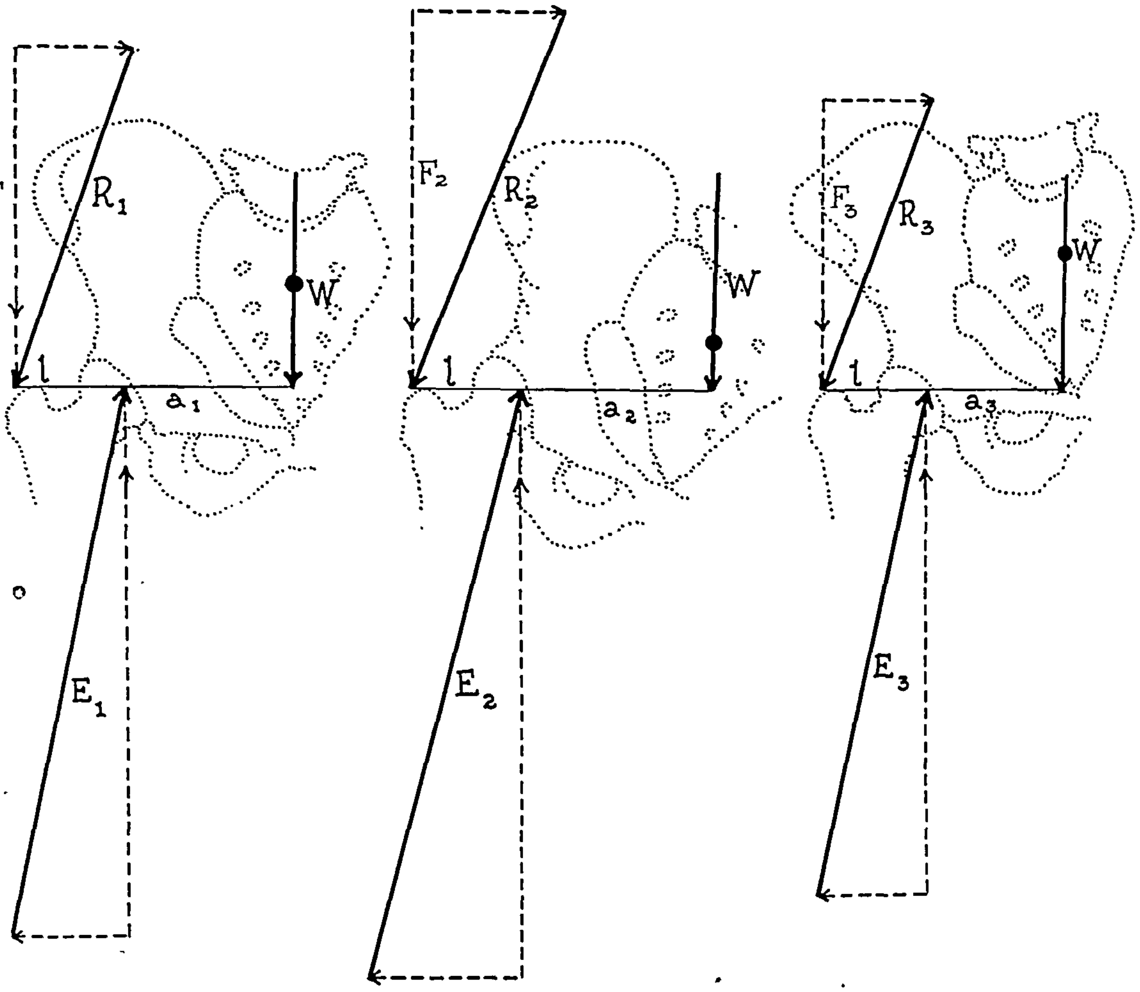

FIG. 7
Final vector diagrams for static forces.

sagging 15 degrees, and (3) with the pelvis elevated 15 degrees on the non-weight-bearing side. These were the positions employed in the experimental investigation of torque. With the pelvis level, the resistant torque about the hip was divided almost equally between the iliotibial tract and the muscles (Table I, Column D). With the pelvis sagging 15 degrees, the torque was resisted almost entirely by fascial tension alone (Table I, Column C); and with the pelvis elevated 15 degrees, the torque was resisted by the muscles alone. In these three positions, the resultant force on the pelvis was determined geometrically by the polygon method (Fig. 6).

The resultant intersected the horizontal plane at approximately the middle of the roughened area of the trochanter for the attachment of the glutaeus minimus. This point was selected as a point of application of the abducting force; the distance from this point to the center of rotation of the hip joint was the length of the lever arm. This distance was measured on the roentgenograms of the experimental subjects. With this measurement, all factors were available to complete force diagrams which included all the major static forces acting in the coronal plane about the hip. An analysis was carried out graphically.

For clarity of presentation, the three steps employed in the graphic solution are illustrated separately (Figs. 5, 6, and 7). Figure 5 indicates the method of calculating the theoretical force, *F*, acting in the vertical plane on the pelvis at the greater trochanter, which is necessary to hold the pelvis in equilibrium against the moment caused by the center of gravity being medial to the center of rotation of the hip joint. Figure 6 shows the manner of calculation, by the polygon method, of the resultant, *R*, of the forces due to the pull of the muscles and the passive tension of the iliotibial tract for the three posi-

which the center of gravity of the supporting extremity deviates from the vertical plane passing through the center of rotation of the femoral head will influence the validity of the calculations; and an attempt must be made to measure the magnitude of this deviation.

The center of gravity of the lower extremities of six cadavera, which had been amputated by the guillotine method through the center of the hip joint, was determined by the familiar method of suspending the extremity in two positions. It was found that the center of gravity in a horizontal plane lay approximately two thirds of the distance from the heel to the hip joint (60.47 per cent. ± 1.17 per cent.), and just medial to the shaft of the femur in the vertical plane. When these data were applied to living subjects, the approximate center of gravity was marked on the thigh; and a plumb line was dropped from a point over the femoral head to the floor. It was found that, in the experimental position, the center of gravity of the extremity did not deviate from the plane of the plumb line more than 1.5 centimeters. Because of this small deviation, it was felt that the assumptions made for the theoretical torque, utilizing the total body weight without correction, were justified.

The minimum theoretical torque was calculated on thirty-five normal individuals (eighteen males and seventeen females) between the ages of nine and fifty-one. In order to determine the center of rotation of the femoral head and the length of the lever arm, roentgenograms of the pelvis of each subject were taken at a distance of six feet. The center of rotation was found by dropping a series of perpendiculars through the mid-points of chords constructed in relationship to the circumference of the femoral head. The distance so established between the center of rotation of each hip joint was measured in centimeters and divided by two, thus providing the distance from the median sagittal plane of the body to the center of rotation of each femoral head (Fig. 3). The subjects were weighed to the nearest tenth of a kilogram. The minimum theoretical value of the torque was then found by multiplying the body weight by the distance from the median sagittal plane to the center of rotation of the hip joint, and expressing the value in kilogram-centimeters.

The magnitude of the torque in kilogram-centimeters was discovered to be, in males, 10.00 ± 0.86 times the body weight in kilograms; and, in females, 9.4 ± 0.97 times the body weight in kilograms.

After these values had been obtained, it was considered desirable to employ some method of checking empirically the theoretical calculations. This was done by the following method, the same subjects being utilized so as to permit a comparison of the value of the theoretical and the experimental torque in each instance.

TORQUE DETERMINED EXPERIMENTALLY

The determination of the experimental values of the torque about the hip joint on the weight-bearing side was based upon myographic recordings. Both skin and needle electrodes were utilized. The electrodes were placed in or over the tensor fasciae femoris, the glutaeus medius, and the glutaeus minimus. The action currents were amplified by means of the Grass electro-encephalograph, and the output was passed through a voltage integrator to facilitate the estimation of the electric potentials.

The action potential was obtained as the individual bore all his weight on the limb to which the electrodes were applied. The opposite extremity was flexed at the hip and the knee, just sufficiently to clear the floor. The abductors necessarily contracted to keep the pelvis level and the degree of contraction was recorded by means of the myograph.

The recorded action potentials so obtained from the abductors were translated into the rotatory force (torque in kilogram-centimeters) exerted by these muscles as they acted to maintain the pelvis level by plotting an experimentally determined force curve, the ordinate indicating the action potential and the abscissa the torque in kilogram centimeters. The loci were determined in the following manner:

latter force exceeds the weight of the body by a ratio of from 1.4:1 to 1.9:1. The minimum static pressure on the head of the femur is approximately 2.4 to 2.6 times the body weight

Normally this force is not borne vertically, but at an angle of approximately 165 to 170 degrees from the vertical and in line with the medial trabeculae of the femoral neck. This static force remains constant in direction, irrespective of whether the pelvis is elevated or depressed on the non-weight-bearing side.

With the knowledge of the *direction* of the reacting force through the head and neck of the femur against the pelvis, the changing angle of the capital epiphysis during growth becomes partially explicable. Close inspection of roentgenograms of the upper end of the femur in individuals of various ages reveals that the epiphyseal line always lies at a right angle to the direction of the medial trabeculae of the femoral neck (Fig. 9). Since the reacting force in the femur follows these trabeculae, there is no sheer on the epiphyseal cartilage. The only force to which it is subjected normally is a compressional one. As growth occurs, with increasing length of the femoral neck and increasing angle of pull of the abductor muscles and the fascia, the epiphyseal cartilaginous plate rotates so as to lie perpendicular to the equilibrant force in the femoral neck.

The interrelationship of these forces becomes altered in cases of paralysis of the abductor muscles and in congenital dislocation of the hip. In the first instance, the loss of muscle power prevents the attainment of equilibrium with the body in a normal position. To prevent the pelvis from rotating toward the non-weight-bearing side, the individual shifts his center of gravity over the affected hip by bending to that side. The resultant forces, acting through the hip, become more nearly vertical. The equilibrant or reacting force in the femoral neck likewise shifts toward the vertical; the epiphyseal cartilaginous plate, remaining perpendicular to these forces, continues to be relatively horizontal; and coxa valga results. This is a constant finding in individuals who have had paralysis early in life, and the degree of coxa valga is in proportion to the loss of muscle power.

Coxa valga occurs in individuals suffering from congenital dislocation of the hip, for the same factors are at work. In these cases, the loss of fulcrum prevents the normal development of the abducting forces. The load is borne vertically on the femur, and the capital epiphysis reacts by remaining horizontal.

Fig. 9

Roentgenograms show the relationship of the capital epiphysis to the medial trabeculae of the femoral neck at various ages: left, at fifteen months; center, at eight years; and right, in the adult.

values was sufficiently great to indicate that factors other than those already taken into account were responsible. The experimental torque, in general, was about one third to one half lower than the corresponding values for the theoretical torque. Further investigations were undertaken to determine the cause of these differences.

The original subjects were studied again but, instead of limiting the myographic recordings to the position where the pelvis was held level while the subject was bearing weight upon one lower extremity, additional recordings were secured as the pelvis was elevated approximately 15 degrees on the non-weight-bearing side and as it was permitted to sag on the non-weight-bearing side until the subject felt completely relaxed. Usually the angle of pelvic sag was about 10 to 20 degrees. In this way, it was felt that the full contraction of the muscles could be recorded without the possible limiting effect of rigid connective-tissue structures, such as fasciae and ligaments, and that the precise influence of these structures could be detected.

As the pelvis was elevated, the action potential of the abductors increased until the experimental torque agreed very closely with the theoretical torque. As the pelvis was permitted to sag, the action potentials gradually decreased until, at a position between 10 and 20 degrees of pelvic tilt, a posture was reached which could be maintained with little or no muscle contraction, as indicated by the action potential. Palpation of the thigh with the pelvis in the sagging position, however, indicated that the fascia lata was tense. The pelvis apparently was prevented from further depression almost entirely by ligamentous pull.

In addition to these observations, the maximum pull of the abductors, expressed as torque (kilogram-centimeters), was calculated for each individual. The results calculated from these data and the conclusions drawn from these results are given below.

COMPARISON OF THEORETICAL AND EXPERIMENTAL TORQUE AND LIMITING FACTORS

The average difference between the theoretical torque and the experimental torque is 9.3 ± 5.7 per cent. for the males, and 8.9 ± 4.9 per cent. for the females. The actual magnitude of the torque in kilogram-centimeters, as established both theoretically and experimentally, is approximately ten times the body weight in kilograms.

It is quite apparent that, when the subject is standing on one extremity with the pelvis level, the force which prevents the pelvis from rotating about the supporting hip is not due entirely to muscle pull. A considerable amount of force is contributed by passive tension on the fascia lata and the iliotibial tract. To cause the passive tension of the ligamentous structures to become slack and to make the muscles alone maintain the full load requires elevation of the opposite buttock and a pelvic tilt of approximately 10 or 15 degrees toward the side of the weight-bearing extremity. As the pelvis is depressed toward the non-weight-bearing side, the fascial structures become increasingly taut and assume a greater and greater degree of the total force, until a point is reached where little or no muscle contraction is required.

After force curves (Fig. 4) have been plotted for each experimental subject, further information can be determined from them. The torque produced by muscle contraction alone, for the three positions of the pelvis, can be read directly from the graphs. The ratio of muscle used to the total muscle power available can be calculated readily. While there are wide individual variations, due to such factors as the shortness of the iliotibial tract and the degree of muscle development, average values have been calculated for the series. The extent of the variation is indicated by the size of the standard deviations. The quantitative data are given in Table I.

The importance of the fascia on the outer portion of the thigh now becomes apparent and, furthermore, helps to explain the great disparity which exists between the mass and size of the abductors, excluding the glutaeus maximus, as compared with that of the adductors, which contribute but a small part toward maintaining the parallelism of the pelvis. The actual combined mass of the glutaeus medius, the glutaeus minimus, and the

THE USE OF HOMOGENOUS BONE GRAFTS

A Preliminary Report on the Bone Bank *

BY LEONARD F. BUSH, M.D., DANVILLE, PENNSYLVANIA

From the New York Orthopaedic Hospital, New York, N. Y.

Since Macewen reported the first successful transplantation of bone from one person to another in 1878, the use of homogenous bone transplants has received only casual notice by orthopaedic surgeons. The reason for this has been twofold: First, the fate of homogenous bone transplants was uncertain; and, second, the preservation and availability of such tissue has been an obstacle. In the past, homografts have been used—especially in difficult cases where autogenous grafts have not been available—in such conditions as osteogenesis imperfecta, congenital pseudarthrosis, and other diseases of the bone in children.

The object of this paper is to review the literature, to report results following the use of homografts of bone in sixty-seven operations, and to report the microscopic studies of biopsies, the effects of blood type and Rh factor, and the methods used in the preservation and storing of bone.

Ghormley, in 1942, reported the use of homogenous and syngenesioplastic (syngenesious †) bone grafts in nineteen operations; eight were failures. In three, homografts were used in cases of congenital pseudarthrosis. Inclan reported the use of homogenous grafts in eight patients with six good results, one fair result, and one failure. Smith reported a series of four cases of osteogenesis imperfecta in which homogenous bone was used with excellent results. Lexer, Gill, and May have transplanted whole or half joints from homogenous sources with what would seem to be surprisingly good results.

Excellent experimental work with animals has been conducted by Macewen, Brooks and Hudson, Keith, Phemister, Murray, Axhausen, Hey Groves, Campbell, Ghormley and Stuck, Haas, Albee, Key, McGaw and Harbin, and Urist; upon their work is based our present knowledge of bone-graft surgery.

The work of some of these authors indicates that the deeper cells of cortical bone die, but that some of the cells near the periosteum, the endosteal surfaces, and the accessible Haversian canals live and grow to form new bone. The new bone develops, either from the surviving bone cells of the graft or from cells of the host, by metaplasia of connective-tissue cells. Finally, the graft is completely replaced by new bone, a process which has been aptly termed by Phemister as creeping substitution, and which Axhausen had previously called *schleichender Ersatz*. Gordon feels that grafts die and are gradually absorbed and replaced.

The studies at the New York Orthopaedic Hospital tend to support the findings of Phemister and others in respect to autogenous grafts. It is felt that a small proportion of bone cells live after transplantation of the graft. Except for the clinical results, the literature gives no information in regard to the histological fate of homografts in the human. Macewen, Ghormley, Inclan, and Smith have reported their clinical results.

Loeb stated recently that, in animals: "The bone marrow, as a rule, survived only under very favorable conditions of syngenesiotransplantation". The bone was preserved, but "it was often difficult to decide whether the cells . . . had come from the surrounding connective tissue, or whether they were actually preserved bone cells".

Armstrong stated, regarding homogenous grafts: "Bone grafts can be successfully transferred from one individual to another should the necessity arise. The donor should be healthy and free from infection, and on no account should a preliminary blood investigation

* Read before the New York Academy of Medicine, February 21, 1947.

† Although previously used as a botanical term, this word seems from its derivation to be appropriate.

TABLE I (*Continued*)

Females												
19	A. S.	12	47.2	410	0	255	405	682	1.2	59.4	0	62.9
20	M. S.	9	32.9	224	34	163	250	430	11.6	58.1	13.6	65.2
21	M. S.	25	51.7	517	17	260	470	865	9.1	54.3	3.6	55.3
22	R. T.	27	59.0	565	56	522	615	1120	8.9	54.9	9.1	84.9
23	S. B.	34	67.6	695	19	224	670	860	3.6	77.9	2.8	33.4
24	W. K.	23	61.7	617	0	312	559	700	9.4	79.9	0	55.8
25	J. C.	20	50.5	482	0	280	460	670	4.6	68.6	0	60.9
26	J. H.	23	55.2	490	17	240	460	1125	6.1	40.9	3.7	52.2
27	D. L.	28	63.5	585	38	568	618	1100	5.6	56.2	6.1	91.9
28	M. L.	25	63.5	585	35	322	553	992	5.5	55.7	6.3	58.2
29	I. I.	34	60.0	568	0	225	430	620	24.3	69.4	0	52.3
30	H. M.	29	68.0	610	0	87	540	860	11.5	62.8	0	16.1
31	L. G.	25	62.6	570	104	273	512	850	10.2	60.2	20.3	53.3
32	A. K.	27	69.3	678	140	574	755	1301	11.3	58.0	18.5	76.0
33	S. T.	21	62.9	592	37	188	527	1052	10.9	50.1	7.0	35.6
34	M. K.	25	61.3	613	20	294	580	1240	5.4	46.8	3 4	50.7
35	V. L.	22	66.0	600	106	411	528	709	12.0	74.4	20.1	77.8
Averages									8.9	60.4	6.8	57.7
Standard deviation									± 4.9	±10.3	± 6.8	±18.2

* Elevation on non-weight-bearing side of 15 to 20 degrees.

A = Percentage differences between the values obtained for the theoretically calculated torque and for the experimentally determined torque.

B = Percentage of the maximum torque possible due to muscular effort, which is required to hold pelvis elevated on non-weight-bearing side.

C = Percentage of muscle contribution to total torque required when pelvis is permitted to sag.

D = Percentage of muscle contribution to total torque required when pelvis is held level.

5. *Blood types*, according to the author's studies, have no bearing on the success or failure of the bone graft. In a series of sixty-seven operations in which homogenous bone was used, careful records were kept of the blood types and the Rh factor of the donors and the recipients. The postoperative course was not influenced by the compatibility or non-compatibility of the blood groups. In identical operations, the morbidity of patients who had autogenous or homogenous grafts, or both, was similar.

Of seventy-three bone donors, the blood was compatible with the recipient's blood in twenty-seven, non-compatible in twenty-eight, and unknown in eighteen. These statistics would indicate that, in considering the use of homogenous bone for grafting, blood-typing studies are unnecessary.

6. *The Rh factor*, which is a property of the red blood cells, has no bearing on the results in the use of homografts.

METHODS OF USING AND STORING BONE

1. *Direct or Immediate Grafting*

Bone may be obtained from other patients upon whom operations are being performed simultaneously, or from relatives who are admitted to the hospital for this purpose; it may be transferred directly from the donor to the recipient. This method of transfer has been used in fifteen instances for homografts and in nine instances for syngenesious grafts.

2. *Delayed Grafting*

Delayed grafting, whether autogenous or homogenous, is the storing of bone in the tissues of a patient for use in secondary operations. This method has been used successfully on several occasions, but should rarely be necessary in institutions where a method of keeping a supply of bone in a bank has been instituted.

3. *Refrigeration*

This is a convenient method of preservation. For tissue to be used in the human, the temperature and duration of storage are important. The following methods of refrigeration have been used in the New York Orthopaedic Hospital:

FIG. 1-A

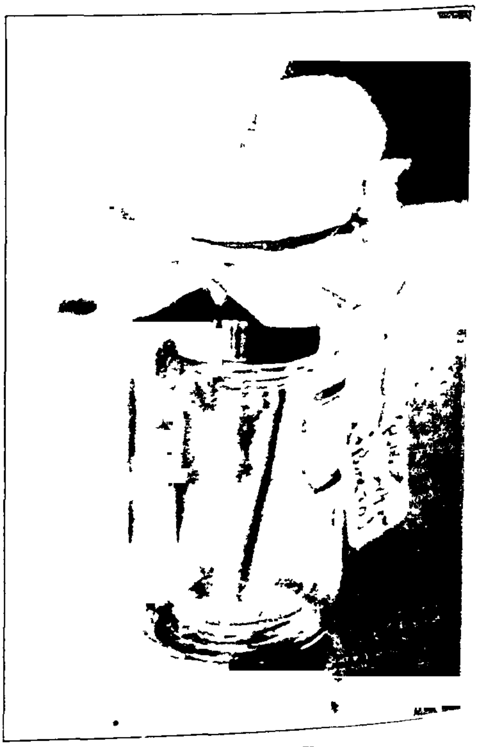

FIG. 1-B

Showing the equipment in which the bone is stored.

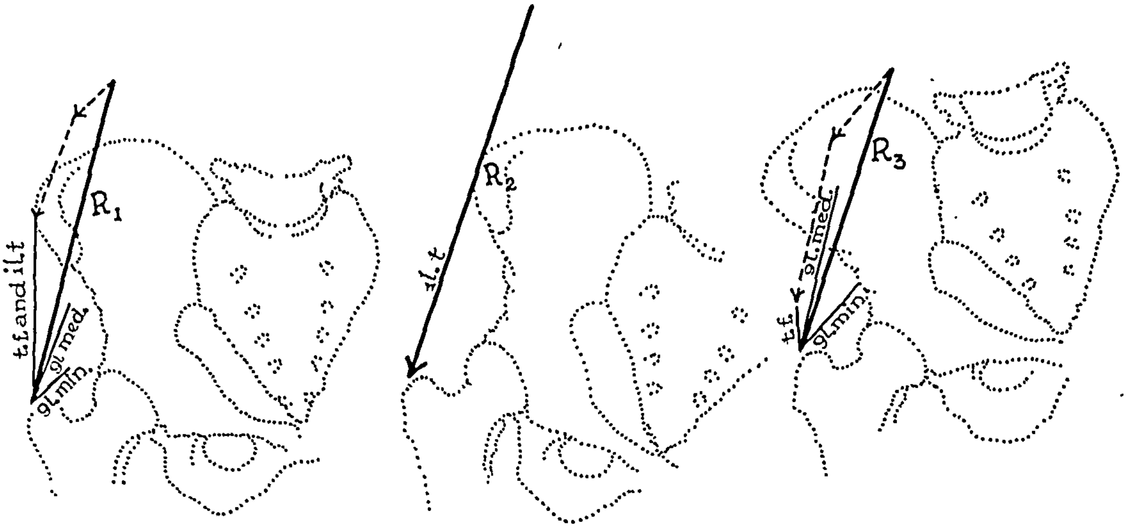

FIG. 6
Method of calculating the resultant, *R*.

The plane selected as horizontal was the one passing through the centers of rotation of both femoral heads. The angles were measured on three cadavera, and average values were calculated. These average angles were taken as determining the *direction* of the forces exerted by the muscles in the construction of a vector diagram.

The greater portion of the glutaeus maximus lay below the center of rotation of the hip joint, and only a minor portion of this muscle could conceivably act as an abductor. This finding corroborated an earlier established observation that no action potential could be obtained from the glutaeus maximus when the body was balanced on one extremity with the hip in complete extension. It was felt to be reasonably certain that the principal muscles involved in preventing pelvic rotation were the tensor fasciae femoris, the glutaeus minimus, and the glutaeus medius, together with the passive resistance of the iliotibial band.

After the direction of the pull of the muscles had been determined, it became necessary to estimate the magnitude of the force exerted by each. This was done by assuming that the force of each muscle would be approximately proportional to its mass. The tensor fasciae femoris, the glutaeus minimus, and the glutaeus medius were dissected carefully from five cadavera. These muscles were cut into small strips and desiccated to a constant dry weight. The ratios of the average muscle masses to each other were as follows:

Tensor fasciae femoris	1
Glutaeus minimus	2
Glutaeus medius	4

For ease of calculation, it was assumed that the point of application of the forces produced by the abductor muscles and the iliotibial tract was at the center of the rough area on the superolateral aspect of the greater trochanter. This was demonstrated to be accurate for the glutaeus medius and the glutaeus minimus, although the line of action of the tensor fasciae femoris fell slightly medial to it. Because of the small contribution of this muscle to the whole, it was felt that the resultant error would not be significant.

With these data, a force diagram could be constructed for the calculation of the resultant of the individual forces caused by the pull of the muscles and the tension of the fascia lata on the pelvis. Each force vector was drawn at the angle determined from roentgenographic studies, with its length in proportion to the muscle mass which i represented. Three positions were utilized: (1) with the pelvis level, (2) with the p

TABLE II

SOURCES OF HOMOGRAFTS OF BONE

Ilium	26
Tibia	19
Ribs	2
Talar bones	12
Phalanges and metatarsals	14
Total	73

enous bone had been employed. Microscopic studies showed the bone spicules to be dead, being surrounded by connective-tissue cells with osteogenesis taking place by metaplasia of these cells, as shown in Figures 3-A, 3-B, 3-C, and 3-D. The homogenous bone, although dead and disintegrating, seems to form a trellis and to act as a stimulus for new-bone formation, and produces the necessary supply of local calcium salts for calcification of the callus. The bone is absorbed or disintegrates, and the cortical fragments are gradually replaced by living bone cells. These findings simulate those of Leriche and Policard, and of Greig.

Excess bone, removed from the ilium during such operations as arthroplasties and fusions of the hip, as well as bone from the tibia and from other sources, is placed in the bank. Prior to storage the bone is cleaned; it is cut into small pieces when used. Cortical bone is usually cut into small strips the shape of match sticks (one to two inches in length

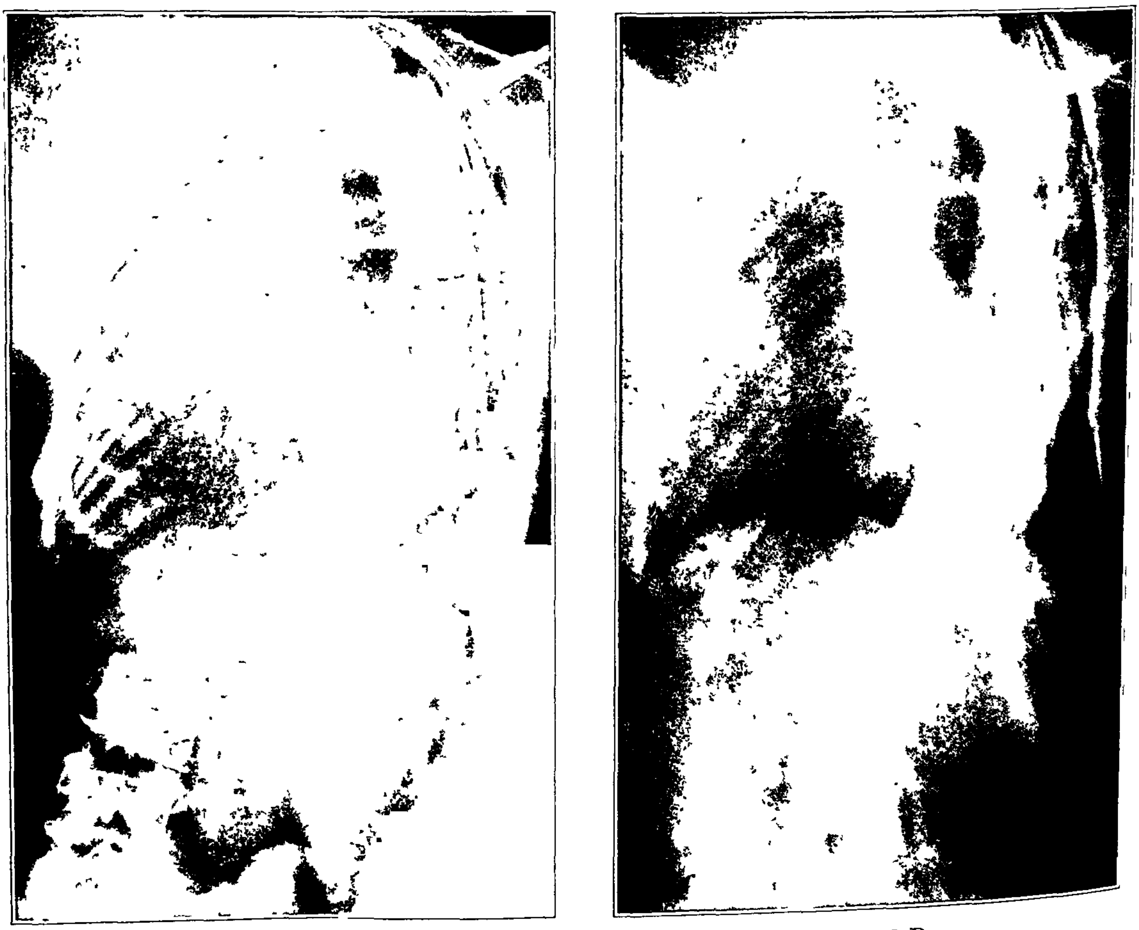

FIG. 2-A FIG. 2-B

Roentgenograms of spine of a patient with severe scoliosis.

Fig. 2-A: Before operation.

Fig. 2-B: After operation. Fusion was performed in three stages; homogenous bone was added at each stage. Excellent fusion was demonstrated by roentgenographic study as well as by direct exploration.

tions of the pelvis. Figure 7 illustrates the final vector diagrams for the static forces, acting in the coronal plane. Both translatory and torsional forces are depicted.

Analysis of the vector diagrams discloses that, because of the interplay between fascial tension and active muscle contraction with *the pelvis in various positions*, the reacting force, E, remains relatively fixed in its angular relationship with the vertical, although its magnitude may vary, due to the shift in the center of gravity.

It can be said, then, that the direction of the reacting force through the head of the femur is *constant and, therefore, independent of the position of the pelvis*. The angle of this force with the vertical is from 165 to 170 degrees.

This observation is significant, for it indicates that the weight of the body normally is not borne vertically on the femur, but at an inclination which corresponds closely with the direction of the medial trabeculae of the femoral neck.

To determine the precise angle between the medial trabeculae of the femoral neck and the vertical, while the subject was bearing weight on one lower extremity, further studies were carried out. Roentgenograms were taken of a group of nine individuals while each was standing on one extremity. The angle of the medial trabeculae was measured directly on the weight-bearing side. This angle measured 169 degrees ± 0.9 degree from the vertical. In addition, the difference between the angle of the neck and the medial trabeculae was measured on thirty-eight roentgenograms, taken at random. The value of this angle (Fig. 8,t) varied slightly in males and females, but averaged 21.1 degrees ± 2.3 degrees (males 21.44 degrees ± 2.16 degrees and females 20.81 degrees ± 1.97 degrees). The average angle of the femoral neck (Fig. 8,n) was determined on 150 roentgenograms of adults, and was found to be 136 degrees ± 7.2 degrees (males 135 degrees ± 6.6 degrees and females 137 degrees ± 7.1 degrees). The average angle of inclination (Fig. 8,i) of the femur was quoted as 9 to 10 degrees by Martin and as 9 to 15 degrees by Walmsley. If the three angles (Fig. 8, i, t, and n) are added, they give the angle of the medial trabeculae with the vertical (Fig. 8,r). The angle of the trabeculae, so determined, lies approximately between 166 and 172 degrees. This value agrees with the direct observation (169 degrees ± 0.9 degree) on the small sample of nine individuals.

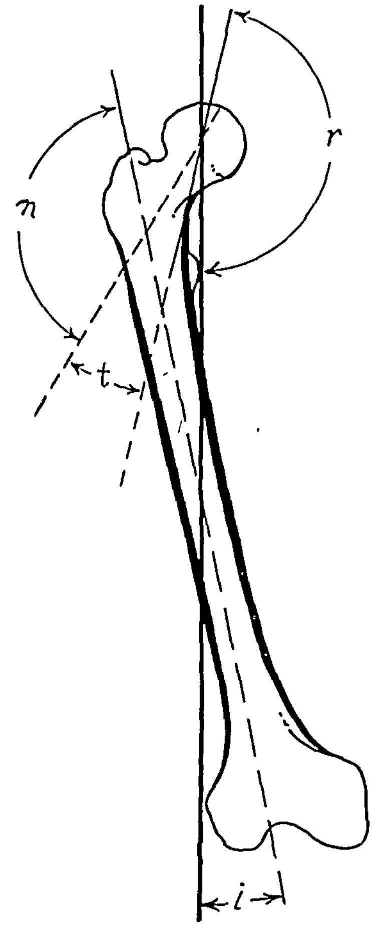

FIG. 8

Determination of angle between medial trabeculae of femoral neck and the vertical.

Attention is now invited to the close agreement between the angle of the reacting force, calculated from the vector diagrams, and the angle of the medial trabeculae of the femoral neck. Only one conclusion is possible, and that is that the resultant force, due to body weight and the pull of the abductor muscles and fascia, is transmitted to the femoral head at an angle, and that the plane of the reacting force or equilibrant in the femoral neck *coincides with that of the medial trabeculae*.

DISCUSSION AND CONCLUSIONS

The study of the forces acting in and around the hip joint explains numerous, apparently unrelated, clinical observations.

The reacting force in the head of the femur resists not merely the pressure of the superincumbent body weight, but, in addition, the force of the abductor muscles and the tension on the iliotibial tract which is necessary to hold the pelvis in equilibrium. This

and approximately one-sixteenth to one-eighth of an inch in width), for placement over the area to be fused. Relatives have been used as donors. As yet, it has not seemed feasible to have paid donors; and this should not be necessary, if extra bone is obtained whenever the opportunity presents itself. When special donors are necessary, a general anaesthetic is given before the bone is removed.

All suitable bone is collected and placed in the deep freezer for future use. The ilium is the best and largest source of cancellous bone; the tibia is best for cortical bone. As may be inferred from the data in Table II, all available bone has been stored.

Autogenous bone may likewise be stored for secondary operations. This procedure has been used on several occasions.

Homogenous bone may be obtained in larger quantities in the future from cases in which trauma has been the cause of death. The bone should be collected and stored immediately after death, and the necessary precautions regarding sterility should be observed.

CLINICAL RESULTS

The excellent results obtained in all but four cases lend testimony to the success of homogenous bone grafts. The use of additional bone, after the Hibbs type of spine fusion has been performed, not only diminishes the possibility of pseudarthrosis, but makes a stronger fused mass to maintain the correction. The operating time is lessened, and secondary incisions or operations for extra bone are eliminated. Examples of the clinical results, as demonstrated by roentgenograms, are shown in Figures 2-A, 2-B, 4-A, 4-B, and 4-C. In patients in whom extra donor bone has been added, there has been no

Fig. 4-A Fig. 4-B Fig. 4-C

Fig. 4-A: Shows a large bone cyst in the upper portion of the tibia, which was filled with homogenous bone chips by direct transfer from donor.
Fig. 4-B: One month after operation. Fig. 4-C: Five months after operation.

The so-called "antalgic" gait of the individual who has a painful disease of the hip joint is of interest. On the surface, it appears rather peculiar that a patient with a painful hip will walk by throwing himself over the painful joint, giving rise to a gait which may be compared with that of a glutaeus medius weakness. By so doing, however, the individual shifts his center of gravity over the hip, thus decreasing the required pull of the abductor muscles. This, in turn, decreases the pressure upon the femoral head from a force of 2.4 to 2.6 times the body weight to simply the superincumbent body weight. This expediency of gait, while decreasing the total load on the femoral head, results in a change in the direction of the reacting force in the femur. Instead of the body weight being borne at an angle which thrusts the head into the acetabulum, the load is carried vertically upon the femur. This alteration in direction of the forces causes changes in the femoral head, which are depicted in the roentgenograms. In malum coxae senilis, the bone changes affect predominantly the superior aspect of the femoral head, because the forces are concentrated there. In epiphysiolysis the assumption of an antalgic gait, while leading to a decrease in the total load on the femur, causes that load to be borne vertically, with the result that a sheer is applied to the epiphyseal plate, which normally is not present. This sheer will facilitate further slipping.

The importance of the abductor muscles and the iliotibial tract in altering the direction of the reacting forces in the femoral neck should be emphasized. Any surgical approach to the hip joint which injures these structures and weakens the forces exerted by them will not only modify the magnitude, but also the direction, of the reacting force through the femoral neck.

NOTE: The writer wishes to express his appreciation to John B. deC. M. Saunders, M.B., Professor of Anatomy, who willingly provided the facilities of his department; and to LeRoy C. Abbott, M.D., Professor of Orthopaedic Surgery, for his interest and encouragement.

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be omitted. There is not sufficient evidence to show if this type of grafting is as uniformly reliable as autogenous grafting, nor do we know what relations such factors as the blood groups of the individuals concerned bear to the prospects of success."

Ghormley has made a somewhat similar statement.

Loeb[21] stated that the "evidence available at present makes very improbable a direct relationship between the four primary blood groups and the individuality differentials of host and donor". Correspondingly, there is little reason to suppose that "the particular genes determining the four blood groups determine also the fate of homoiogenous transplants . . ." Thus the four blood groups cannot be identified with the individuality differentials.

In order that homotransplants of bone may be available for use, methods of storing and preservation must be considered.

Key has recently reported successful results in the use of delayed bone grafts. Inclan stored bone in citrated blood at +5 degrees centigrade. Matthews reported the successful use of autogenous skin grafts which had been stored for twenty-one days in a household refrigerator at from +3 degrees to +6 degrees centigrade. Waterman showed that chick embryos were preserved best at +5 degrees centigrade. After refrigeration for twenty-two days, epidermis, cartilage, bone, and some skeletal muscle grew, while all other tissues died. Carrel, in 1912, reported storing tissues from an infant at +3 degrees centigrade; skin grew after forty-two days. Carrel quoted several French investigators, including Tuffier and Magitot, who preserved tissues such as bone, cartilage, and peritoneum up to two months by refrigeration, and transplanted them with good results.

Strumia and Hodge have frozen skin in plasma at from −20 degrees to −25 degrees centigrade for one to six days, with unusual success. Webster stored skin in a frozen state with good results. All grafts refrigerated for more than three weeks melted away. Keith froze bone chips in liquid air for ten minutes. Subsequent roentgenograms showed only a fair growth of bone, and microscopic examination of the tissue showed only a small amount of new-bone formation. Keith stated that this finding was a surprise.

Turner showed that the treponemata of yaws and syphilis retain their motility and virulence in rabbits after exposure to a temperature of −78 degrees centigrade for four months. Thus, until otherwise shown, all bone donors should have negative Kline or Kahn reactions.

Brooks and Hudson, and Keith showed that age was important, in that grafting of bone in young animals was 100 per cent. successful, while in old animals 40 per cent. of failures were recorded.

Loeb's extensive experiments in many species[22] indicate that grafts of the various tissues are successful in the following order: autogenous, syngenesioplastic, and homogenous. Carrel and Strumia have shown that tissues, stored or washed in saline or Ringer's solution, are less successful when transplanted. Apparently some important substance is washed from the tissues which is necessary for growth.

Some of the pertinent facts, based on experimentation or on clinical experience in relation to bone grafts, are as follows:

1. *Regeneration* in bone-grafting takes place only when the grafts are in contact with living bone. This occurs chiefly by metaplasia of connective-tissue cells. This process has been demonstrated in autogenous and homogenous bone grafts, as well as in simple fractures.

2. *Age* is important in that grafts have proved to be more successful in the young than in the aged.

3. *Sulfonamides* inhibit bone calcification, as the experiments of Benesch, Chance, and Glynn have shown.

4. *Cortical bone* is best for stability, while *cancellous bone* is preferred for osteogenesis.

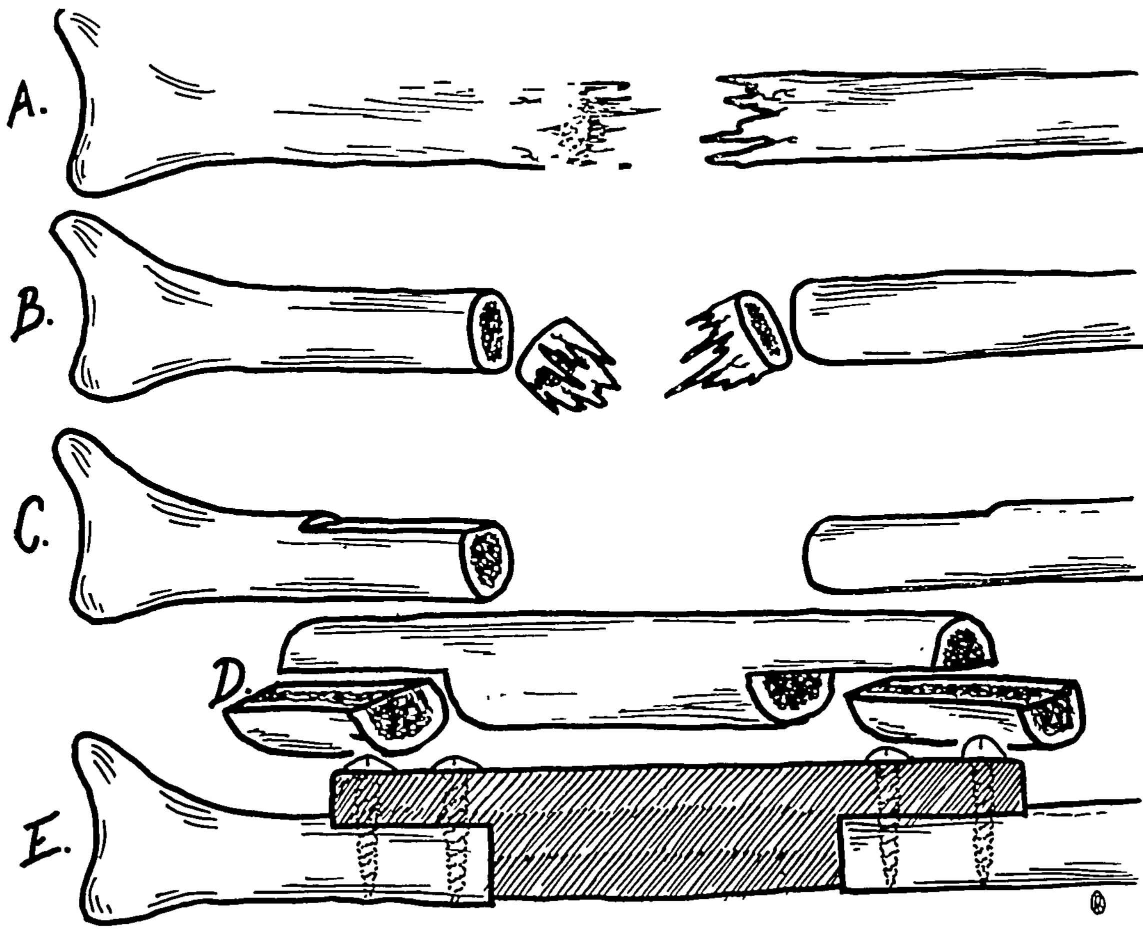

FIG. 1

Diagram of operative procedure for insertion of fibular graft.
A: Subperiosteal exposure of fragments of radius.
B: "Squaring" of bone ends, with removal of sclerotic bone.
C: Preparation of fragments to receive the graft.
D: Fibular graft, cut to fit the radial defect. The two small fragments of the graft are discarded.
E: The shaded area represents the fibular graft fixed to the radial fragments with Vitallium screws.

there is any question as to whether or not simple excision of a scar will give an adequate soft-tissue covering. It is advisable to wait at least six or eight weeks after complete healing of a pedicle graft before an operation is performed beneath it. Care must also be taken not to undermine more than 50 per cent. of the width of the pedicle graft, because of the danger of impairing circulation to the edge of the flap.

Sequestrectomy, curettage of sinuses, and removal of foreign bodies are performed as required to produce complete healing. As soon as all drainage has ceased and healing of the wound is complete, time is the greatest ally in producing a sterile field for the insertion of the bone graft. At present, the authors require a minimum of twelve weeks, if there has been no difficulty in healing. If active bone infection has been present, a longer period—up to six months—may be considered necessary. Penicillin is given in doses of 20,000 units every three hours for twenty-four hours before operation.

OPERATIVE REPAIR

The fibular graft is obtained from a normal leg, preferably that on the side opposite the fractured arm, to give the second surgical team more room in which to work. The fibular shaft is exposed subperiosteally through a lateral longitudinal incision, dissection being carried down along the posterior intermuscular septum between the peroneal and soleus muscles. Care is taken not to injure these muscles. A measured amount of fibula is then removed with a Gigli saw or osteotome. The length of the graft may be calculated before operation by adding three inches to the length of the radial defect. Proximally, as

Regular Refrigeration (+2 degrees to +5 degrees centigrade): Bone may be stored at this temperature for periods up to three weeks. The bone is stored under sterile conditions in a glass, screw-top container, which is placed within a similar, larger bottle. An additional precaution to maintain sterility is to place a piece of sterile rubber sheeting (5 by 5 inches) over the top of the bottle; on this is placed a piece of gauze (4 by 5 inches), both of which are fastened securely in place by a strong rubber band (Figs. 1-A and 1-B). Such containers prevent contamination at the time of removal of the bone, evaporation, and sudden changes of temperature. This method of storage has been used by the author in thirty-seven instances.

Deep Freezing (−25 degrees centigrade): Experiments on rabbits, performed by C. Zent Garber, M.D., and the author, prove the safety of this method for the preservation and storage of rabbit bone for an indefinite period of time. The results of these experiments will be reported in another paper. The bone is stored in the type of containers just described. This method has been used in thirty instances in the human.

With both types of refrigeration, the bone is warmed to room temperature before being used. Bone which has been preserved under these conditions has the appearance of fresh bone.

Special precautions must be taken in establishing a bone bank. The bone obtained for this purpose must be free from infection or disease. A card index is kept, in which the following data are recorded for each specimen of bone: the donor's name and hospital number; the source of the bone; the Kline or Kahn reaction; a history of recent jaundice, malaria, or infections; the date of storage; and the weight of the bone. When the bone has been used, the date of use and the name of the recipient are recorded, and the card is filed.

Homogenous bone grafts have been used in sixty-seven operations (Table I), performed on fifty patients, with bone from seventy-three donors (Table II). Syngenesious grafts were used in nine children in operations for congenital pseudarthrosis, osteogenesis imperfecta, and large bone cysts. The excellent results obtained in this entire series of patients, as well as the minimum complications experienced, have been very encouraging.

It has been possible to study the areas of fusion in which homogenous bone has been added in such cases as scoliosis, where multistage operations are performed. Large, solid fused masses with abundant new-bone formation have been found. An exploration, performed on a patient who had had three operations in which bone from three different donors was used, showed a wide, thick, continuous fusion throughout the area in which the operations had been performed (Figs. 2-A and 2-B). These findings have likewise been evident in the roentgenograms in this series of cases.

Biopsy specimens were removed from twelve of these areas of fusion, in which homog-

TABLE I

TYPES OF OPERATIONS IN WHICH HOMOGENOUS BONE GRAFTS HAVE BEEN USED

Operation	Number
Fusion of the spine for:	
Scoliosis	33
Tuberculosis	2
Lumbosacral defects	8
Fusion of the ankle	3
Fusion of the wrist	2
Fusion of the hip joint	2
Onlay bone grafts	12
Grafting the cavities in osteitis fibrosis cystica	5
Total	67

TABLE I

CLINICAL FINDINGS

Case No.	Length of Defect (*Inches*)	Length of Graft (*Inches*)	Time of Immobilization in Cast (*Weeks*)	Time of Immobilization in Brace (*Weeks*)	Operative Procedures: Skin Graft	Operative Procedures: Resection of Distal Portion of Ulna	Results
1	2	5	14	10	Yes	Yes	Union; good rotation
2	$1\frac{1}{4}$	4	16	0	Yes	No	Union; poor rotation
3	1	4	16	14	No	No	Infection; graft sequestrated; eventual bony union by involucrum. Rotation very much restricted
4	$1\frac{1}{2}$	5	16	0	No	Yes	Union; good rotation
5	1	4	16	0	Yes	Yes	Union; good rotation
6	2	5	18	0	No	Yes	Union; good rotation
7	$1\frac{1}{2}$	$4\frac{1}{2}$	18	0	No	Yes	Union; good rotation
8	$1\frac{1}{4}$	4	20	0	No	No	Union; poor rotation
9	$5\frac{1}{2}$	$8\frac{1}{2}$	20	20	Yes	Yes	Union; poor rotation
10	$1\frac{3}{4}$	5	18	0	No	Yes	Union; good rotation
11	2	$4\frac{1}{2}$	20	0	Yes	Yes	Union; good rotation
12	$1\frac{1}{2}$	4	18	0	No	Yes	Union; good rotation
13	3	$6\frac{1}{2}$	14	12	No	No	Union; good rotation
14	2	5	16	—	No	No	Failure; infection developed after 8 weeks. Graft was absorbed
15	$1\frac{1}{4}$	$4\frac{1}{2}$	16	8	Yes	Yes	Union; good rotation
16	$1\frac{1}{2}$	5	12	—	Yes	Yes	Partial union; still in brace

screws in each fragment; but occasionally a single screw and a loop of tantalum wire have been employed to obviate weakening the graft by a second screw hole. In some instances, the distal fragment is so osteoporotic that screws will not hold; and in these cases two double strands of No. 22 tantalum wire have been used. The wound is then closed in layers, and a long plaster cast is applied, with the elbow at a right angle and the forearm in neutral position.

POSTOPERATIVE CARE

The cast should be heavily padded to allow for postoperative swelling. In addition, suspension straps are incorporated in the cast to keep the arm elevated for a period of at least forty-eight hours after the operation. The patient is then told that he may lower his arm whenever he wishes. As a rule, the patient finds that the arm is more comfortable when it is elevated, and he seldom lowers it before the third or fourth day after the operation.

The patients are allowed to be ambulatory as soon as the leg wound has healed, which usually is on the tenth day. Frequently an elastic bandage is employed to prevent swelling in the leg. No definite instructions are given about walking, other than reassurance; and the patients are permitted to be up and around as soon as they feel comfortably able to do so. At first they are somewhat hesitant to walk on the leg, and they may use a crutch or cane. Within a period of two or three weeks, they are ambulatory without support, but they may still limp slightly. Within a month after removal of the graft, nearly all complaints referable to the donor site have disappeared, and the patients are ambulatory without limp.

FIG. 3-A

FIG. 3-B

Microscopic studies of bone removed from areas of spine fusion in which homogenous bone was used.

Fig. 3-A: Bone from the ilium was stored for fifteen days at +2 degrees centigrade; the specimen was removed twenty-one days after transplantation. Shows necrosis and erosion of bone spicule with marginal new-bone formation on one side.

Fig. 3-B: Bone from ilium, stored five days at +2 degrees centigrade, was removed from fused area after twenty-three days. Small chips of necrotic bone are present, with considerable new osteoid tissue and some new-bone formation in fibrous stroma.

FIG. 3-C

FIG. 3-D

Fig. 3-C: Bone from ilium used by direct transplantation. Specimen, removed for study forty-three days later, shows necrosis and erosion of bone chips with formation of some new marginal bone.

Fig. 3-D: Bone from ilium used by direct transplantation. Specimen, removed for study 100 days later, shows extensive new-bone formation by "creeping substitution", replacing necrotic bone.

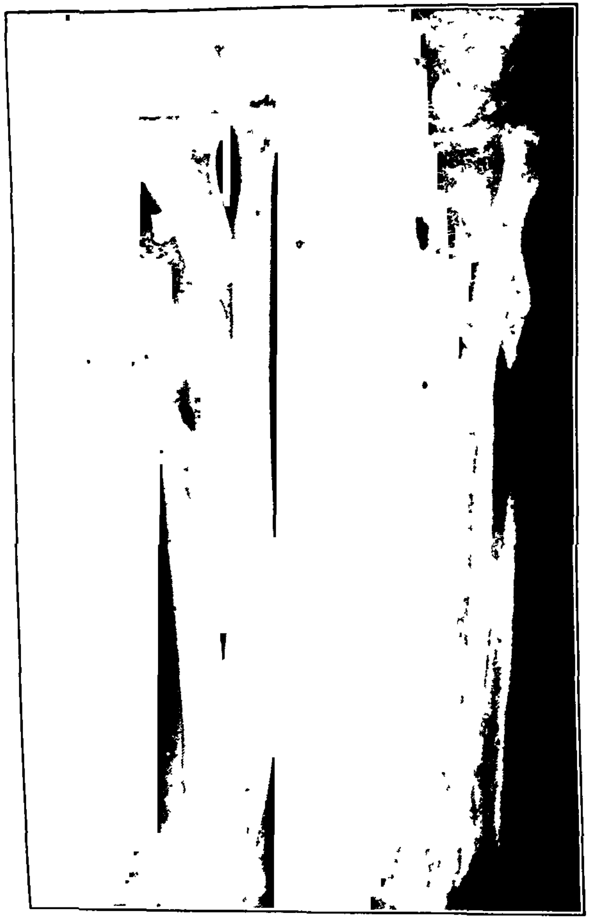

Fig. 2-C

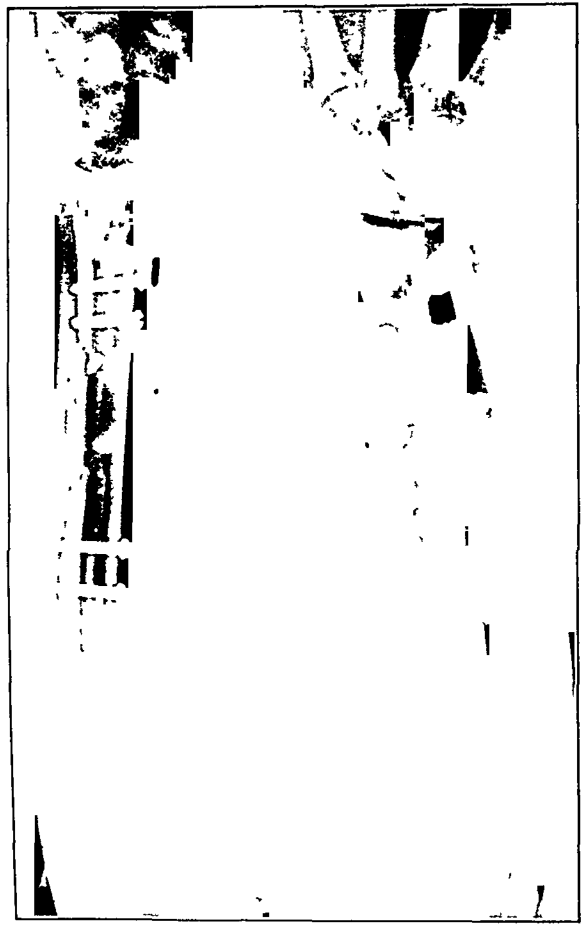

Fig. 2-D

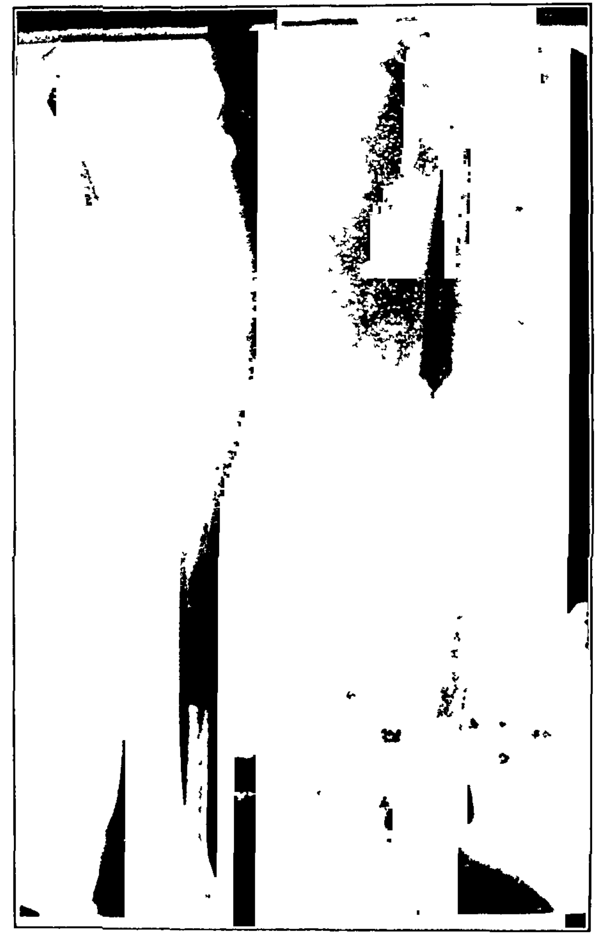

Fig. 2-E

Fig. 2-C: Anteroposterior and lateral roentgenograms of forearm, six months after injury. Note the angulation of the distal fragment of the radius.

Fig. 2-D: Anteroposterior and lateral roentgenograms of forearm, three months after insertion of fibular graft and resection of the distal end of the ulna. The two metallic fragments in the soft tissues were not encountered at time of operation and were, therefore, not removed.

Fig. 2-E: Anteroposterior and lateral roentgenograms of leg, three months after removal of fibular graft. Note the minimum regeneration of the fibula. Patient had no complaints referable to leg.

pseudarthrosis to date. A comparative study will be made of this series of cases with a previous series in which no extra bone was added.

COMPLICATIONS

Four complications which were experienced could have been expected had autogenous bone been used under similar circumstances. Homogenous grafts were used in two instances in the presence of infective arthritis; sequestration and draining sinuses resulted, which eventually healed. On the basis of our present knowledge as to the fate of homografts, as shown in the microscopic studies, this is to be expected. In the third patient, removal of bone fragments was required on two occasions, because of inability to maintain soft-tissue closure over the grafts. Microscopic study of the bone fragments removed from this patient showed the deeper areas to have definite metaplasia, with new-bone formation surrounding the dead graft. This was a syngenesious cortical graft, which was used in the repair of an ununited fracture in the presence of osteogenesis imperfecta. The ununited fracture healed, despite this complication. The fourth complication was in a patient with congenital pseudarthrosis of the tibia, which was grafted with cortical grafts from the mother. Union was accomplished, but subsequently a fracture occurred through the grafts with the development of a large callus over each graft, indicating the ability of the bone to regenerate.

SUMMARY

1. Homogenous bone may be used as a transplant under the same conditions as, or in conjunction with, autogenous bone.

2. The blood type has been shown to have no influence on the successful use of homogenous grafts of bone, nor does the Rh factor influence transplantation results.

3. Bone may be stored safely in sealed containers at from +2 degrees to +5 degrees centigrade, for periods up to three weeks. Bone may be preserved in sealed containers in the deep freezer at approximately −25 degrees centigrade for an indefinite period.

4. Microscopic studies of bone, removed from fused areas in which homogenous bone had been used, showed the grafts to be dead, but surrounded by connective tissue undergoing metaplasia and new-bone formation.

5. The success of homografts of bone has been shown by clinical results, by direct inspection of the fused area, and by roentgenographic examination.

6. Homografts of bone, available in a bone bank, will eliminate a second operation upon a normal ilium or tibia, with its possible complications; and will shorten the time of operation and of hospitalization.

7. Homogenous bone grafts were used in sixty-seven operations, with but four complications.

NOTE: The author wishes to express his appreciation to Alan DeForest Smith, M.D., for his cooperation in this work; to C. Zent Garber, M.D., whose excellent counsel and advice have been most valuable; and to William H. Von Lackum, M.D., whose forethought, enthusiasm, and inspiration caused this work to be undertaken.

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THE REPAIR OF DEFECTS OF THE RADIUS WITH FIBULAR BONE GRAFTS

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Medical Corps, Army of the United States

Compound fractures of the radius, with loss of bone substance and resultant non-union, are not frequently encountered in civil life. Among the thousands of casualties treated on the Orthopaedic Service of a large Army General Hospital, however, such fractures are seen quite frequently. Over a period of eighteen months, the authors treated sixteen of these cases with fibular bone grafts.

The type of fracture under consideration usually results from a perforating wound of the forearm by a high-velocity missile. A portion of the radial shaft is more or less completely destroyed, so that no satisfactory bridge of bone remains between the major fragments to permit healing of the fracture. This report is concerned primarily with those cases in which the radial shaft was irreparably damaged, and in which the ulna either was spared entirely or sustained a fracture which had healed. Obviously, many of these cases also have associated nerve damage, as well as massive loss of muscle and skin.

Characteristic of the deformity is the prominence of the distal end of the ulna and the marked radial deviation of the hand (Fig. 2-A), resulting from shortening of the radius. Loss of active pronation and supination of the hand occurs when the defect in the radial shaft is distal to the insertion of the pronator teres. In these cases, the proximal fragment of the radius may be felt to pronate and supinate in a satisfactory manner; but the hand will not rotate, because of the loss of bony continuity of the radius. The strong rotators (biceps brachii, supinator, and pronator teres) no longer can act on the distal fragment of the radius, and the weak rotators (brachioradialis and pronator quadratus) have either been damaged by the original injury or are not strong enough to perform any appreciable rotation of the wrist and hand. In addition to abnormalities due to loss of bone, there frequently is loss of extension power in the fingers and thumb. In some of the cases, this is due to a severance of the deep branch of the radial nerve; in other cases, it may be due to actual avulsion of muscle substance.

There are both advantages and disadvantages in the use of fibular grafts. The fibular graft has the advantage of providing considerable stability to the grafted bone. Furthermore, the fibula is approximately the same size as the radius; so that ultimately, when healing is complete, the normal contour and probably the normal strength of the radius have been restored. Finally, the use of a fibular graft will avoid the infrequent, but ever imminent, complication of fracture through a tibial donor site. The primary disadvantage of the fibular graft is its relatively greater degree of dense cortical bone, as compared to tibial or iliac grafts. The osteogenic properties of the fibular graft are, therefore, not so great as those of a tibial or iliac graft. To obviate this disadvantage, it has been suggested that the drilling of multiple small holes throughout the graft might increase the vascularity and the rapidity of "take". This procedure has not been employed in any of the cases presented.

PREOPERATIVE CARE

Prior to operation, every effort must be made to eliminate all scar tissue that might break down. If the scar is narrow and the skin edges may be approximated without tension, the bone-grafting may be done at the time the scar is excised. The authors feel, however, that it is a much better plan to excise the scar first, and insert the bone graft at a second operation. A tubed pedicle graft or an abdominal-flap graft must be employed whenever

much of the fibula as desired may be removed; this may, if necessary, include the head of the bone. It is, of course, necessary to spare the peroneal nerve as it rounds the neck of the fibula. Distally, at least three inches of the fibula must remain to maintain the stability of the ankle mortise.

By obtaining the graft in this manner, there have been few spontaneous complaints and no objective evidence of disability in the leg. In the majority of instances, only on close questioning did patients state that the leg did not possess quite the stamina that it had had before operation.

The distal end of the ulna is first excised subperiosteally through a longitudinal incision, one and one-half inches long. In a few instances, a slip of palmaris longus tendon was removed at the same time; this was used to encircle the ulna and anchor it down to the flexor carpi ulnaris. This procedure prevents the tendency for dislocation of the ulna when the arm is rotated; but, in the authors' experience, there has not been a great deal of difference symptomatically or functionally between those cases in which the ulna has been anchored to the flexor carpi ulnaris and those in which it has been left free.

The reasons for resection of the distal portion of the ulna at the time of operation justify a word of explanation. In the first patient upon whom this operation was performed, it became obvious that such resection was necessary. It was found, after exposure of the radius, that the marked deviation of the distal fragment of the radius could not be corrected, even though the fragment had been completely exposed subperiosteally. After removal of the distal end of the ulna, the distal fragment of the radius was freely movable and could be readily aligned with the proximal fragment. Subsequent to this, in most cases the operation has been begun by resection of the ulna. This facilitates the operation and also eliminates a later operation, which would probably be necessary to restore rotation to the forearm and correct the radial deviation of the hand.

Next, an adequate longitudinal incision is made over the fractured area of the radius. The exact site of the incision is determined by the location of the fracture and by the previous scarring. As a general rule, it has been found best to employ a dorsolateral incision. The superficial branch of the radial nerve is identified and protected throughout the operation. Dissection is carried down through muscle planes, usually between the extensor carpi radialis longus and the brachioradialis; and the radial fragments are exposed subperiosteally for a distance of at least one and one-half inches. Scar tissue and devitalized bone fragments are removed from the site of non-union. The ends of both radial fragments are sawed back at right angles to the shaft, until the sclerotic portion has been removed and good vascular bone is apparent (Fig. 1,*B*). This usually requires a resection of approximately one-quarter to one-half inch from each fragment.

Half the thickness of the fibular graft is then sawed from each end of the graft, leaving a central portion, which is the full thickness of the fibular shaft and measures exactly the same length as the bone defect to be bridged (Fig. 1,*D*). Care must be taken not to extend the saw cuts more than half way across the fibular shaft, in order to prevent the possibility of fracture of the graft in this area.

The radial fragments are aligned, and the decision is made as to whether the graft should be applied to the lateral or posterior surface. The corresponding surfaces of the radial fragments are then leveled down with an osteotome, so that exact contact may be obtained between the graft and each fragment (Fig. 1,*C*). If the length of the radial defect was measured while traction was being applied to the hand, the fibular graft may be mortised in snugly between the radial fragments. When the traction has been released, the end of each radial fragment will come up tightly against half of the fibular shaft, and the half-thickness ends of the fibular graft will lie as onlay grafts of approximately one and one-half inches, in close contact with the freshened area on each radial fragment (Fig. 1,*E*).

The graft is held in place by metallic fixation. The authors usually use two Vitallium

The bulky arm cast is removed, the wound inspected, and the sutures removed any time after the eighteenth day after operation. By this time the cast has become somewhat loose, and it must be replaced by a snug-fitting cast with only a minimum amount of padding. The hand portion of the cast is trimmed back sufficiently to permit full motion in the fingers and thumb. These casts are usually changed at six-week intervals, and the progress of bone healing is checked by means of roentgenograms. A cast is usually worn for at least four months, and then a brace of metal and leather may be applied to give further support for another two or three months. The graft must be protected against fracture until roentgenograms show that it has been well incorporated into the radius.

Physical therapy may be instituted to mobilize the elbow and wrist as soon as the arm has been removed permanently from the plaster cast. Forceful active or passive rotation of the forearm is not permitted, however, until roentgenograms show complete healing.

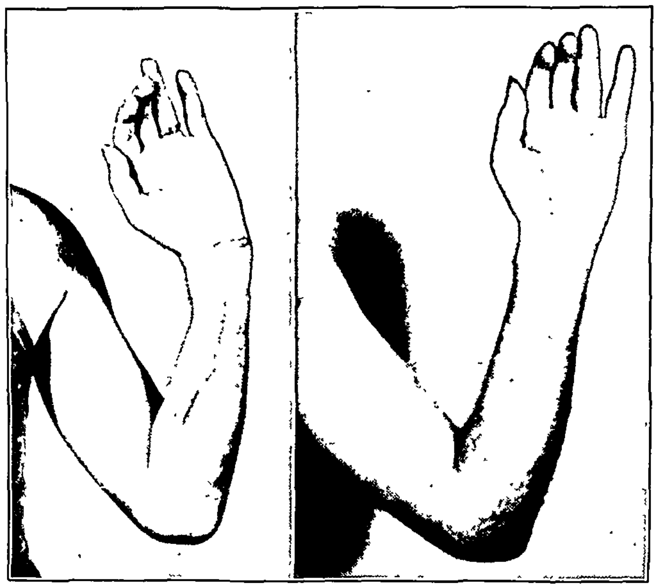

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 4. Preoperative condition of forearm, showing radial deviation of hand and prominence of ulnar styloid.

Fig. 2-B: Postoperative condition of forearm, showing correction of deformity and restoration of normal contour of forearm.

COMPLICATIONS

One complication that has constantly to be guarded against is that of infection. In the present series, this occurred in two cases; in one case the purulent drainage had its onset twelve weeks after the operation, and in the other case it occurred eight weeks after operation. In addition to the precautions taken in regard to the skin of the forearm and the time interval between cessation of drainage and insertion of the bone graft, penicillin is administered for one day before operation and both penicillin and sulfadiazine are given for at least six or seven days after operation, or until the patient has remained afebrile for at least three days and there is no longer any undue swelling in the hand or other evidence of infection in the arm. Sulfadiazine may aid in controlling some of the organisms which are not especially sensitive to penicillin; but the administration of sulfadiazine is not considered absolutely essential if penicillin can be given.

Another complication to be considered is fracture of the bone graft. Although this did not occur in this series of cases of fracture of the radius, two instances of fracture were seen in which a similar type of graft was employed on a defect of the ulna. In both of these cases, the trauma was minimum. In one case, the arm was still immobilized in a plaster cast; in the other case, all immobilization had been removed two months before the patient's transfer to our care. Both of these fractures occurred at the junction of the graft and the ulnar fragment. This indicates that very accurate contact between the graft and the fracture fragments should be obtained, so that healing will occur, not only between the onlay portion of the graft and the fragments, but also between the fragments and the portion of the graft that is mortised in between the ends of the bone.

Fibular grafts are probably revascularized more slowly than similar grafts removed from the tibia or ilium. To avoid the possibility of fracture of the graft, immobilization in plaster casts should be maintained for at least fourteen to eighteen weeks, followed by

In order to obtain a perfectly satisfactory fixation in this form of osteosynthesis, the following rules should be observed carefully:

1. The nail should have a sharply oblique position in the neck.

2. The nail should be inserted *without splintering* the bone around the wire guide at the place where it is driven in.

3. The transverse channel in the head of the nail should be adjusted in such a direction that the screw will pass diametrically through the femur, with support in both the inner and outer cortices.

4. The length of the nail should be measured exactly. The point of the nail should lie one centimeter below the joint surface of the head of the femur. If the nail is too short, defective fixation of the head and neck fragments will result; if it is too long, there is the risk that the nail may penetrate into the joint.

FIG. 9

Type of fracture not suitable for this method of osteosynthesis.

The majority (about 80 per cent.) of the intertrochanteric and pertrochanteric fractures of the femur are suited for treatment by this method. Pertrochanteric fractures approaching the subtrochanteric type, as well as fractures with cracks running down into the shaft fragment, on the other hand, are not suitable for such treatment (Fig. 9). The essential condition for osteosynthesis is a satisfactory position of the fracture during manipulated reposition on a fracture table. If, in exceptional cases, a satisfactory fracture position cannot be obtained, the operation should not be performed. Cases not suited for this procedure have been treated with balanced traction.

Advanced age and general infirmity are not contra-indications, provided the patient is not in such a bad condition that other methods of treatment are likewise contra-indicated. Some of the patients were operated upon under low-spinal anaesthesia. In the majority, however, intravenous narcosis was produced with narcotal in combination with nitrous oxide; this method seems preferable.

During the period from January 1945 to April 1946, thirty patients, whose ages averaged seventy-seven years, were operated upon at Sabbatsberg Hospital. The mortality rate during their stay in the Hospital was 10 per cent. Two of the patients who died were eighty-five years of age; the third was eighty-three. They were very infirm and died of generalized arteriosclerosis with senile marasmus and terminal bronchopneumonia.

Dissection in two of these cases showed the fixation to be satisfactory. In the third case it was not satisfactory. The reason was that, while the nail was being driven in, the bone had been cracked as far as the region of the fracture. The operator had not followed the preliminary procedure described here. Redisplacement of the fragments after the operation occurred in one of the other cases. In this case, which was one of the first, the operator had not managed to get the screw through the femur; it skirted the rear part of the bone.

These two cases illustrate the importance of an exact technique. In the other case, the position of the fracture had remained unchanged despite mobile treatment.

After the operation, the patient was allowed to lie freely in bed, as after an operation for fracture of the neck of the femur, and at once to begin to move the extremity. When he

Fig. 3-A

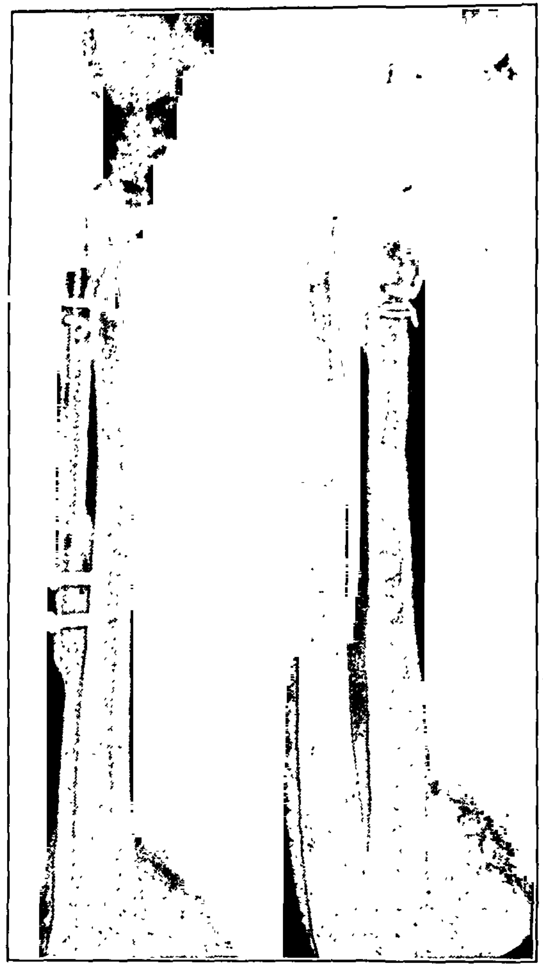

Fig. 3-B

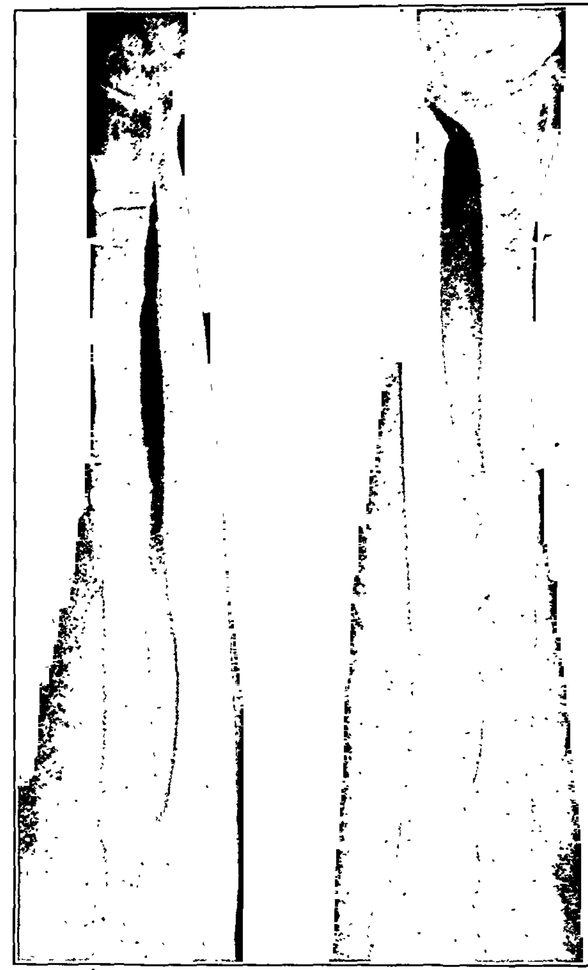

Fig. 4

Fig. 3-A: Case 11. Lateral and anteroposterior roentgenograms of forearm, five months after injury. Note the relative increase in length of the ulna.

Fig. 3-B: Lateral and anteroposterior roentgenograms of forearm, four and one-half months after insertion of fibular graft. Because of marked osteoporosis of distal fragment of radius, it was necessary to fix the graft to this fragment with two loops of tantalum wire.

Fig. 4: Case 1. Lateral and anteroposterior roentgenograms of forearm, eleven months after insertion of fibular graft. Patient has excellent range of motion in wrist and good rotation in forearm. The fibular graft has been well incorporated and the normal radial contour has been restored.

OPERATIVE TREATMENT OF PARALYTIC GENU RECURVATUM

BY CLARENCE H. HEYMAN, M.D., CLEVELAND, OHIO

Genu recurvatum resulting from infantile paralysis is unsightly, and sometimes produces a severely disabling deformity. It is usually associated with such an extensive disability of the entire extremity that other factors, in addition to the back-knee, necessitate the wearing of a brace; and alleviation of the disability at the knee alone does not materially benefit the patient. If stabilization of the knee will enable the patient to walk without a brace, or if it appears likely that a mild deformity will progress, correction by operation is indicated.

Genu recurvatum may be caused by infantile paralysis in cases in which an excessive and continual strain is exerted upon the posterior capsular ligaments at the knee, causing them to stretch. Paralysis of the hamstrings or gastrocnemius, or especially paralysis of both, is a contributing factor. The deformity may also be a result of leverage force, exerted upon the back of the knee by a short Achilles tendon in the presence of paralyzed hamstrings. The repeated backward thrusts of the hyperextended knee stretch the collateral and cruciate ligaments, allowing still more hyperextension. Eventually, structural deformity of the condyles of the tibia, consisting of a downward inclination of the anterior portion of the articular surface, furthers the abnormality and adds to the difficulty of correcting it. Correction of the condition before bone deformity occurs is, of course, desirable.

Correction of genu recurvatum requires, first of all, elimination of as many of the contributing factors as possible. Operations upon the knee itself are directed toward strengthening or reinforcing the posterior ligamentous structures, the construction of a bone block anteriorly, or elevation of the anterior articular surface of the tibia. These supports are passive in function. The author knows of no way to provide active resistance to hyperextension.

In the absence of bone deformity, the writer has tried to construct check ligaments, because this method appears rational and is conservative. Two operations have been devised,—one to enhance the function of the collateral ligaments in resisting hyperextension, and the other to construct a check ligament behind the knee. Each has given good results and is indicated in certain conditions.

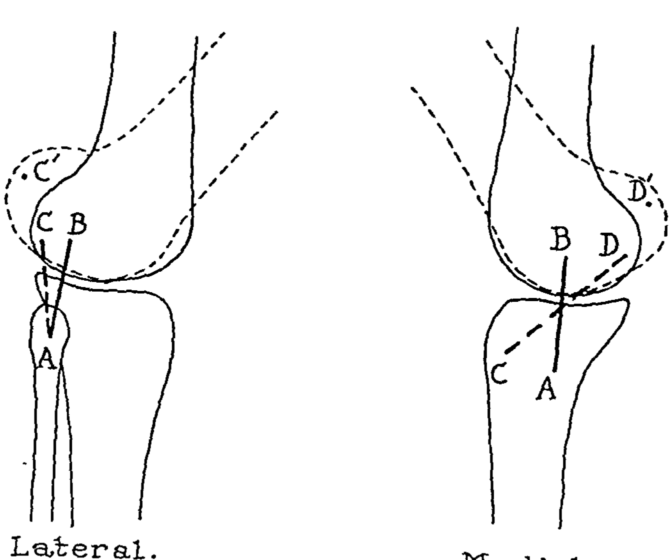

FIG. 1

The fibular and tibial collateral ligaments are represented by the heavy lines *AB*. The interrupted lines *AC* and *CD* represent newly constructed ligaments with the femoral attachments shifted posteriorly. *C'* and *D'* are the attachments of *C* and *D*, respectively, with the knee in recurvatum, which would be impossible if the band held. Reconstruction of the collateral ligaments according to this plan corrects lateral instability as well as genu recurvatum.

If there is no bone abnormality, hyperextension of the knee is prevented by competent anterior cruciate and collateral ligaments; and it would appear to be rational that genu recurvatum could be corrected by reconstruction of the collateral ligaments in a position which would augment their resistance to hyperextension. This has been accomplished by reattaching the femoral insertions of reconstructed collateral ligaments at a point more posterior on the femoral condyles. A description of such an

OSTEOSYNTHESIS OF INTERTROCHANTERIC AND PERTROCHANTERIC FRACTURES OF THE FEMUR

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In distinction from subcapital and transcervical fractures, which usually are intracapsular, the intertrochanteric and pertrochanteric fractures of the femur, which run extracapsularly, show a favorable healing tendency and, in this respect, may be regarded as "benign" fractures. In these fractures, with relatively few exceptions, reposition entails no great difficulties. The method of treatment usually adopted is wire traction through the tuberosity of the tibia or the lower end of the femur.

The disadvantages and hazards of traction treatment are particularly evident in these fractures, for the following reasons:

1. The ages of the patients as a rule are high, averaging over seventy years. According to Spotoft, they are higher than for fractures of the neck of the femur.

2. Except in certain fractures, where there is no displacement of the fragments, the wire traction should be continued for ten, twelve, or fourteen weeks. Coxa vara may occur at a very late stage—after the lapse of several months—even if the patient had not been allowed to put his weight on the fractured extremity. [5] The lengthy immobilization is very trying for these aged patients and, in a considerable number of cases, their condition is such that the traction treatment either cannot be applied consistently or must be discontinued prematurely.

3. The amount of traction should be about one-tenth of the body weight, and careful supervision with frequent roentgenograms is required. Healing in a coxa vara position is by no means infrequent. The limb has a strong tendency toward outward rotation. Even if healing in this faulty position does not affect the hip joint greatly, it is unfavorable for the function of the knee joint.

4. Traction treatment also has local drawbacks. In many cases a traction wire which has been retained a long time becomes a focus of infection, which, however, usually heals rapidly after the wire has been removed. If the wire has been applied supracondylarly through the femur, however, the infection frequently leads to cicatrization in the quadriceps and the formation of adhesions around and in the suprapatellar recess, with permanent restriction of the mobility of the joint. If the wire slips, the risk of pyarthrosis in the knee joint is imminent. Even if the wire is placed below the knee joint, through the tuberosity of the tibia, traction treatment for some length of time may entail protracted symptoms in the knee joint. For these fractures, the patient usually must stay in the hospital about four or five months. For certain fractures without displacement, the hospital stay is somewhat shorter; but for various fractures with a markedly faulty position, as well as in cases where complications supervene, it is considerably longer.

The intertrochanteric and pertrochanteric fractures of the femur produce a higher mortality rate than do fractures of the neck. Key stated that, at St. Louis City Hospital the mortality rate in a series of 214 fractures in the trochanteric region was 38 per cent., whereas the mortality for 166 intracapsular fractures of the neck at the same Hospital was 25.9 per cent. Both groups were treated in the same way. Siler and Caldwell found a mortality rate of 30.1 per cent. in 103 cases. In Speed's 118 cases, the mortality was 18.6 per cent. Wadstein, in thirty-one cases, had a mortality rate of 32 per cent. The author can unreservedly endorse Lippmann's statement that "the death rate is considera'· higher than the severity of the original injury would indicate . . ."

operation was published by the author in 1924, and this is believed to have been the first operation designed to correct genu recurvatum by the construction of ligamentous or fascial resistance to hyperextension. In brief, this consisted of a modification of the Edwards operation for reconstruction of the collateral ligaments in which the biceps tendon, or a portion of it, is implanted into the posterior aspect of the lateral condyle of the femur, and is reinforced by turning down a strip of fascia lata to form an insertion into the head of the fibula. The tendons of the semitendinosus and gracilis are implanted into the posterior aspect of the medial condyle of the femur to reinforce the tibial collateral ligament. These structures on both sides of the knee, extending from below upward and backward, check not only lateral mobility, but also a backward thrust of the femur on the tibia. The basic principle of the operation is shown in Figure 1, and the important operative steps are outlined in Figures 2, 3, 4, and 5. Other methods to construct check ligaments have been described by Colonna in 1930, Gill in 1931, and Carrell in 1937.

Construction of an anterior bone block was described by Campbell in 1918. Mayer adopted this in principle, but modified the technique. Brett, in 1935, reported good results by elevating the tibial plateau anteriorly in cases in which bone deformity was the cause of genu recurvatum; Campbell accomplished this by a subcondylar osteotomy, and maintained elevation by inserting cancellous bone into the gap. Irwin, in 1942, described a method of subcondylar osteotomy of the tibia whereby the tibial plateau was lowered posteriorly. Sutherland and Rowe modified Brett's operation by inserting a metal wedge anteriorly, only 0.5 centimeter distal to the anterior articular surface of the tibia. They stated that Brett's operation could be done prior to closure of the epiphysis, although Brett, in a second paper, specified lateral stability and adult bone growth as prerequisites. Other methods of treatment have been arthrodesis of the knee and supracondylar osteotomy of the femur. Arthrodesis results in the disability of a stiff knee, and is contraindicated in bilateral cases. Osteotomy of the femur does not appear to be rational.

It is not intended in this paper to pass judgment upon the efficacy of a bone block at the knee. It would seem from a purely speculative consideration, however, that an anterior bone block would have no effect upon the lateral instability which so frequently accompanies genu recurvatum. Mayer had this experience, and found it necessary to construct additional blocks of bone at the sides of the knee in an attempt to correct lateral instability, which persisted after the construction of an anterior bone block. There is also the possibility of a subsequent traumatic arthritis, since a bone block cannot conform so accurately to the articular surface of the femur as does the olecranon surface to the humerus. An osteoplastic method of restoring the normal plane of inclination of the tibial plateau is indicated when bone deformity is a major factor in genu recurvatum. Brett's operation is limited by his prerequisites of lateral stability and adult bone growth, and it would appear that subcondylar osteotomy of the tibia would not correct lateral instability.

Reconstruction of the collateral ligaments by implanting the attachment at a position more posterior on the femoral condyles has been done in a small number of cases. They are not numerous, because at least fair strength in the quadriceps is necessary to lock the knee, and there must be sufficient strength in other muscles of the extremity and sufficient stability at the hip and foot to enable the patient to walk without a brace. Good stability has been maintained in five of seven operations performed according to this method, with recurrence of deformity to not more than a mild degree, not necessitating the wearing of a brace. The first patient operated upon and reported in 1924, with a bilateral deformity, was lost from observation two years after operation, but reappeared unexpectedly fifteen years later while passing through Cleveland on a "hitchhike" trip from the West Coast. During this trip, he had frequently walked ten miles a day. There was excellent stability of both knees, and only slight hyperextension. In another patient, also a bilateral case, and in a third, a unilateral case, no recurrence of disabling genu recurvatum is known to have occurred ten years after the operations. Failures occurred in two cases; these were

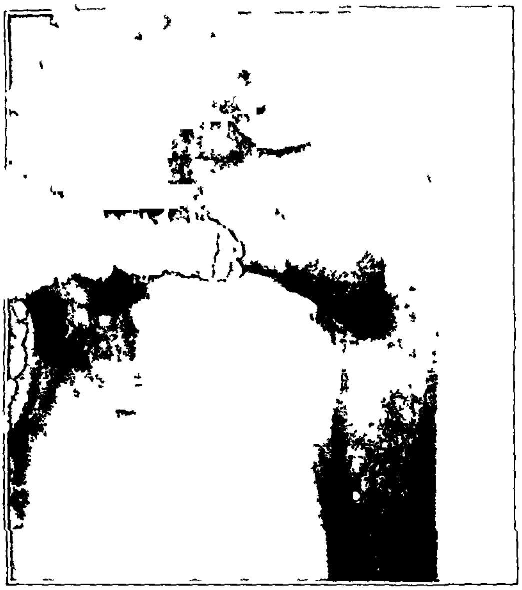

FIG. 2-A
Fracture before operation.

FIG. 3-A
Fracture before operation.

FIG 2-B
After osteosynthesis.

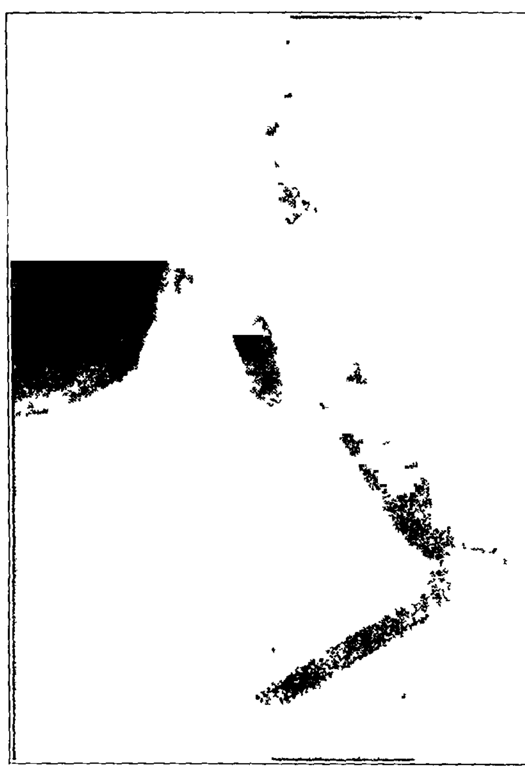

FIG. 3-B
After osteosynthesis.

In order to avoid the disadvantages of traction treatment and to enable the injured patients to move more freely, osteosynthesis of these fractures has been recommended by Sven Johansson, Brittain, Moore, Spotoft, Watson-Jones, and others. In Sweden, the procedures most commonly adopted for osteosynthesis of fractures of the neck of the femur are Sven Johansson's method with Smith-Petersen's three-flanged nail and Nyström's method with multiple nails. Each of these procedures, however, is suitable only in exceptional cases of these fractures.

At the Sabbatsberg Hospital, Smith-Petersen's three-flanged nail with a transverse

femur, and is continued downward over the medial aspect of the tibia. The periosteum covering the medial condyles of the femur and tibia is incised immediately posterior to the tibial collateral ligament, and the posterior surfaces of the lower end of the femur and upper end of the tibia are exposed subperiosteally. The origin of the inner head of the gastrocnemius is detached from the bone with this dissection. Obliquely directed drill holes are then made through the lower end of the femur, proximal to the epiphyseal plate, and through the upper end of the tibia, distal to the epiphyseal plate, in such a direction that their exits are at the posterior aspects of these bones. While the knee is supported in flexion of 30 degrees, the excised tendon is passed through the drill holes, and the protruding ends are sutured to the anterior margin of the periosteal sheath. Tension should be sufficient to make the tendon taut and to resist extension of the knee beyond an angle of 150 degrees. This direct implantation of a tendon or fascial strip through a hole is more reliable for security than is a superficial cortical or periosteal attachment, and solves the difficulty formerly experienced when dealing with osteoporotic bone. During closure of the wound and application of the plaster bandage, the knee is supported at an angle of 150 degrees. It is expected that there will be some give afterward, allowing complete extension.

In the presence of a weak or paralyzed quadriceps, it is imperative that complete extension of the knee be possible. In fact, a slight back-knee is desired in this situation to provide stability. Accordingly, three weeks after operation the cast is bivalved, and the flexed knee is extended gently by the surgeon. This is not delegated to a physiotherapist, for the surgeon alone can estimate the tautness of the posterior structures and can be guided accordingly in the future stretching needed to obtain complete extension. The knee is then replaced in the bivalved cast in the originally flexed position. Experience has shown that six weeks' protection in the cast is sufficient. The patient is then allowed liberty of movement without weight-bearing. If progress toward obtaining complete extension is slow, gentle stretching by the physiotherapist is instituted until almost complete extension is possible. A convalescent walking brace, limiting extension just short of 180 degrees, is worn for three months.

Since the check ligament passes across the joint to insertions beyond the epiphyseal plates, a pertinent question arises as to the likelihood of an unyielding fascial or tendinous structure causing flexion deformity of the knee with growth. This has not been observed. Perhaps growth may act favorably by maintaining tautness of the check ligament, which would compensate for any possible stretching. Late roentgenograms of the knee after operation have shown no appreciable disturbance of growth. One cannot say with certainty the lower age limit at which a check ligament may be implanted across the epiphyseal line at the knee, but caution would dissuade one from doing it on a patient under the age of twelve.

Tenodesis, as described, has been performed upon three patients, aged ten years, thirteen years, and fourteen years, respectively. The first operation was done in 1931. This patient had a severe forward subluxation of the tibia in addition to genu recurvatum. The knee had remained in good stability when the patient was last seen, three years after operation. The other two patients were operated upon in 1933 and 1940, and were demonstrated before the Clinical Orthopaedic Society in Cleveland in 1941. Neither patient is wearing a brace; there has been no recurrence of deformity; and there is no flexion contracture.

SELECTION OF CASES SUITABLE FOR OPERATION

Stabilization of the knee to correct paralytic genu recurvatum is indicated when correction of the disability would enable the patient to walk without a brace to support the knee; and perhaps it should be done in the mild case, in order to prevent an increasing deformity with ultimate malformation of the tibial condyles. The strength of the quadriceps

THE USE OF ABSORBABLE SUBSTANCES TO OBLITERATE BONE CAVITIES AND AS HEMOSTATIC AGENTS IN OPERATIVE PROCEDURES ON BONES AND JOINTS *

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THE USE OF ABSORBABLE SUBSTANCES TO OBLITERATE BONE CAVITIES

In the course of a project on the use of penicillin in the therapy of chronic osteomyelitis, the authors have resorted to the primary closure of wounds resulting from the surgical procedures. The details of the technique and the results obtained have been reported elsewhere [1,2] and, therefore, need to be described only briefly in this report.

The technique consists of the intramuscular administration of penicillin at three-hour intervals for approximately twenty-four hours prior to a thorough saucerization of the osteomyelitic focus (under tourniquet control, whenever feasible), and the removal of all diseased and scarred overlying soft tissues. After the proper toilet of the wound with saline solution, the cavity is flooded with normal saline containing 250 units of penicillin per cubic centimeter of fluid. The wound is then firmly closed in several layers without drainage. Adjacent sinus tracts are excised, whenever possible, and closed without drainage. If such a procedure is not feasible, the tracts are curetted and their openings are sealed with several sutures. Gauze soaked in penicillin-saline solution is used as a dressing, and the parts are immobilized in a huge compression bandage of sheet wadding, flannel bandage, and adhesive tape. The intramuscular administration of penicillin, started on the day before the operative procedure, is continued uninterruptedly for a period of ten to fourteen days after operation, depending upon the patient's range of temperature and upon the character of healing of the wound. The dosage of penicillin varies with the sensitivity of the micro-organism to the antibiotic. In those instances in which the organisms are sensitive to 0.2 unit or less of penicillin per cubic centimeter, 20,000 units per dose are ordinarily given. When the micro-organisms are resistant to 0.3 unit or more, 30,000 or 40,000 units per dose are given. The concentration of the penicillin used locally has, in all instances, been 250 units per cubic centimeter of normal saline solution. The compression bandage and dressing are usually not disturbed until the tenth day after operation, at which time the wound is usually found to be either completely or very nearly healed by first intention. The sutures are removed at this time.

The treatment of chronic osteomyelitis by saucerization and primary closure of the wound under antibiotic influences has brought with it the problem of control of the hematoma which develops in the resultant bone cavity. The use of intramuscular injections of penicillin before and after the operative procedure and of local applications of penicillin before closure of the operative wound, without drainage, has been found to control infection, if the procedure has been sufficiently thorough, until the hematoma becomes adequately organized to resist infection. It has further been noted that, if the hematoma is too large to be organized rapidly, a sinus results. This reestablishes the cavity and exposes the operative site to reinfection from without, with resultant delay or failure of healing.

Procedure

In an attempt to fill the bone cavity and to control the continued oozing from the operative site, the authors have used absorbable gauze (oxycel) [5,6,15,16] and absorbable

* This work was done largely as a collateral study to a project on the use of penicillin in the treatment of suppurative lesions with special reference to chronic osteomyelitis, under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and the Hospital for Joint Diseases.

was able to lift the limb from the bed, and when the general condition permitted, he was allowed to sit in a chair. After about four or five weeks, he began to stand on the limb. The hospital stay averaged fifty-five days. Upon discharge from the Hospital, the patients were able to walk, with the support of a stick, and the mobility of their hip joints and knee joints was satisfactory.

SUMMARY

Intertrochanteric and pertrochanteric fractures of the femur, with respect to healing, may be regarded as benign fractures. The patients most apt to incur these fractures are the aged, and the mortality rate is high. Methods of treatment that require a lengthy confinement in bed should be avoided.

The operative procedure reported, which was used in thirty cases at the Sabbatsberg Hospital, is not more serious than that employed in cases of fracture of the neck of the femur. If performed correctly in suitable cases, it gives satisfactory internal fixation and permits early mobilization. The injured patient is easily cared for, so that the work of the nursing staff is lightened; the patient more rapidly recovers mobility and capacity for walking; and the hospital stay is shortened.

The mortality in this series of thirty cases was 10 per cent. The number of cases is too small to enable one to judge whether or not this operative procedure has produced a real reduction in mortality.

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TABLE I (*Continued*)

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
56–82	Saucerization of femur	None	Healed by first intention.
{57–83 / 57–84	Saucerization of humerus and ulna	None	Healed by first intention; wound over ulna somewhat irritated.
62–89	Resection of rib	None	Healed by first intention.
67–96	Saucerization of interphalangeal joint	None	Healed by first intention.
68–97	Resection of second toe and metatarsal and overlying ulcer	None	Slight maceration of skin in web. Healed on forty-first day after operation.
71–166	Saucerization of fused lumbosacral region of spine and buttock	None	Healed by first intention.
73–103	Saucerization of calcaneus	None	Healed by first intention.
75–105	Saucerization of tibia	None	Healed by first intention except for small area which was expected to slough, because o atrophy and embarrassment of circulatio of skin.
77–107	Saucerization of femur	None	Healed by first intention.
78–108	Saucerization of tibia and plastic repair of skin	None	Healed on forty-first day after operation, subsequent to spontaneous evacuation of hematoma and necrosis of small area of skin flap.
80–110	Resection of middle half of fibula	Gelfoam and thrombin	Healed by first intention, subsequent to slight bloody discharge and prolonged fluctuation at operative site. This resolved without further discharge.
81–111	Saucerization of femur	None	Healed on fifteenth day after operation except for several small granulating areas which healed on thirtieth day after operation.
84–114	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Healed by first intention.
86–116	Saucerization of lower jaw	Gelfoam and 1,500 units of thrombin	Persistent slight sterile drainage, which was sanguineous at onset.
87–117	Saucerization of femur and plastic repair of skin on opposite side of thigh	Gelfoam and 1,500 units of thrombin	Considerable oozing into dressings. Temperature began to fluctuate to over 103 degrees. Wound explored on fourteenth day. Considerable slough and foul discharge. *Bacillus proteus* isolated at primary and secondary operations. Result: failure.
87–147	Saucerization of femur	None	Wound broke down on twentieth day after operation and hematoma was evacuated. Healed on forty-fifth postoperative day.
89–122	Saucerization of hip joint	None	Wound not dressed for six weeks, when plaster-of-Paris spica was removed. Wound found healed except for some irritation at stitch holes.
90–123	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Severe hemorrhage on seventh postoperative day, necessitating administration of plasma for shock. Diastasis of wound. Secondary closure on thirteenth postoperative day, after evacuation of clot. Slight discharge. Healed on twenty-ninth day.
92–125	Saucerization of tibia and plastic repair of skin	Gelfoam and 1,500 units of thrombin	Skin edges of lower half of wound sloughed. Healed on forty-first day after operation.

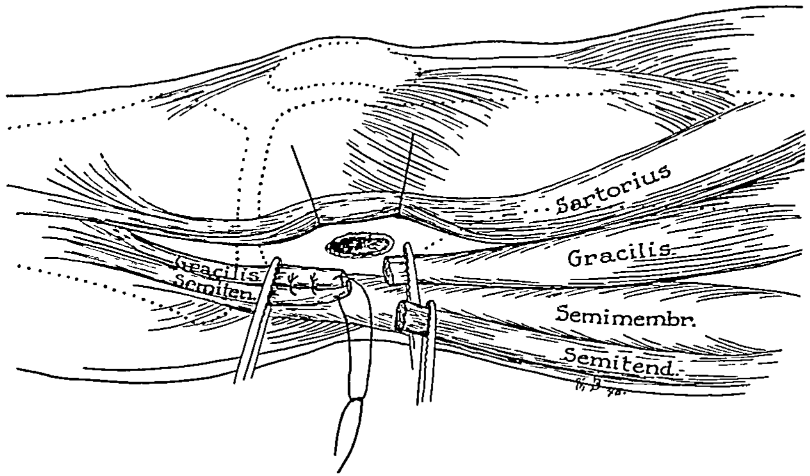

Fig. 2

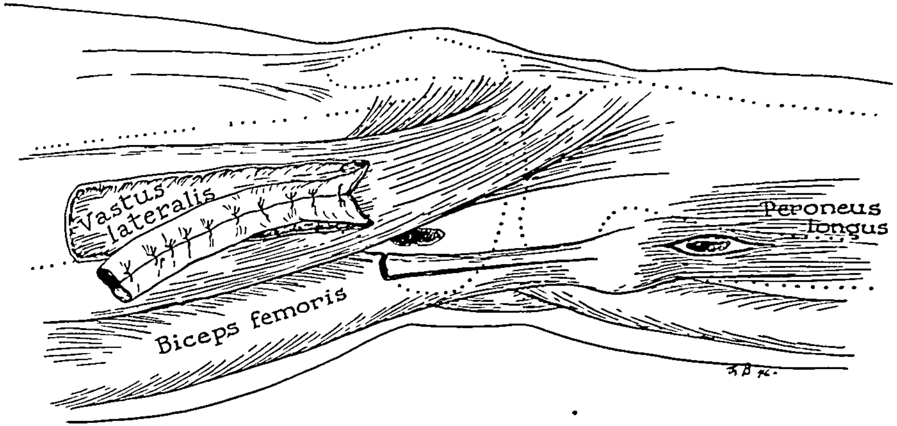

Fig. 4

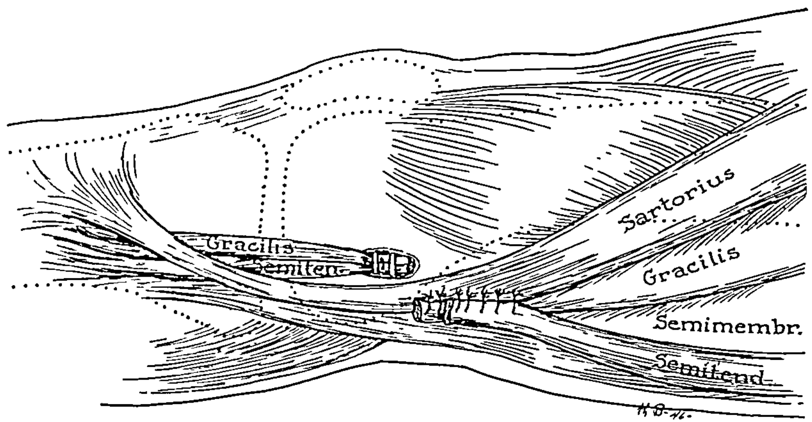

Fig. 3

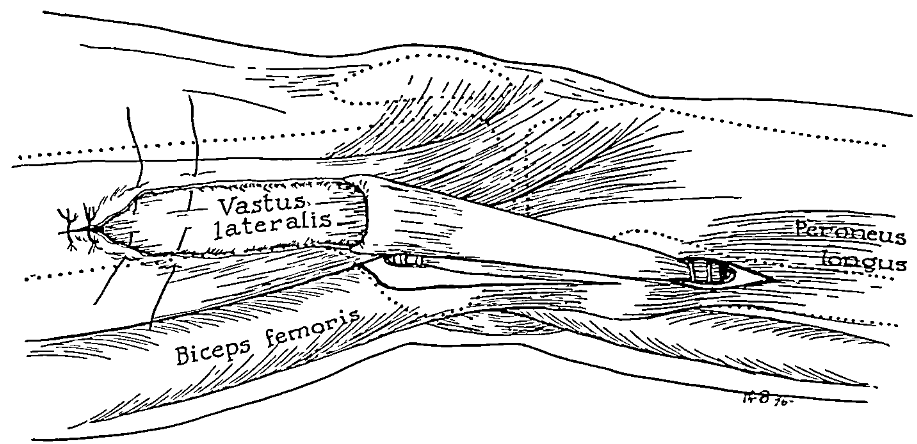

Fig. 5

Figs. 2 and 3: Show the method of utilizing the tendons of the gracilis and semitendinosus for tenodesis, implanting them into the posterior aspect of the internal condyle of the femur to reconstruct a tibial collateral ligament which enhances resistance to hyperextension.

Figs. 4 and 5: Show the method of reconstructing the fibular collateral ligament, utilizing the biceps tendon and a tube of fascia lata. This will also resist hyperextension.

units of thrombin was usually dissolved in fifteen cubic centimeters of normal salin containing 250 units of penicillin per cubic centimeter of fluid. The gelfoam was the immersed in the thrombin-penicillin-saline solution. When it had been thoroughly soaked it was kneaded to expel any remaining bubbles of air, and reimmersed in the thrombir penicillin-saline solution until it had absorbed the maximum amount of fluid. The gelfoai was then pressed into sites from which bleeding was anticipated. Since gelfoam become gelatinous at this stage, firm packing could not be effected and close adhesion could not b obtained. Here, too, the wounds were flooded with saline solution containing penicillir closed firmly without drainage, and dressed as described previously, before the tourniquε control was released.

Results

In Table I are listed all of the cases with chronic osteomyelitic lesions in whicl operations were performed during the greater part of the project and in which the wound were closed without drainage. Included are instances in which oxycel or gelfoam wa used to provide partial obliteration of the postoperative dead space and also to provide a hemostatic agent to lessen the amount of oozing, subsequent to the closure of the wound. Included in this series are also those lesions in which the hemostatic and filling agents were not used. These may, therefore, be considered as control cases, because they were in a general way similar to the cases in which absorbable substances were used.

In thirty-six of the total of fifty-three operative procedures, no absorbable substances were utilized. In seventeen of these, healing by first intention had occurred on the tenth postoperative day, at the time of removal of the sutures, without any complicating factor affecting the nature or time of healing. In twelve instances there were complicating hematomata, accompanied by the spontaneous discharge of blood or serum or some slight irritation of the wound, with resultant delay, but nevertheless good healing of the wounds. In five instances, all of which involved lesions of the tibiae, there was skin necrosis due to embarrassment of circulation, incidental to the operative procedures, in areas in which the circulation had been somewhat embarrassed, although competent, before the operation. Some of these complications were anticipated. All except one of these lesions have eventually healed without further operative interference. There were two failures of healing, due to inadequate operative procedures.

In six of the fifty-three operative procedures, oxycel was used as a partial filler of the resultant dead space and as a hemostatic agent. There was no instance of healing by first intention without complication. In four lesions, spontaneous drainage of hematomata or some other irritation of the wound delayed healing. In two instances, there were failures of healing, due to inadequate removal of the disease focus.

In eleven of the fifty-three operative procedures (Table I), gelfoam was used as a hemostatic, as a vehicle for penicillin, and for partial filling of the dead space resulting from the surgical excision. One of the eleven lesions had healed by first intention at the time of removal of the sutures, on the tenth postoperative day. In nine lesions, spontaneous evacuation of hematomata or other complicating irritations resulted in some delay of wound healing. In one of these nine (Case 90–123), the only one in the entire series, a severe hemorrhage occurred on the seventh day after operation, necessitating the immediate administration of plasma to combat shock, and the eventual operative removal of the blood clot and successful secondary closure of the wound without the use of any hemostatic or filling agent. One lesion (Case 92–125) of the tibia which, in addition to the saucerization, was subjected to a dermatoplasty, was complicated by a sloughing of part of the wound edges, due to embarrassment of the circulation. This lesion eventually healed well without a further operative procedure. In another instance (Case 87–117) there was considerable oozing into the dressings and irregularities of temperature, necessitating the operative exploration of the wound. Considerable slough and foul discharge

attributed to osteoporosis of the femoral condyles, which prevented a secure anchorage of the reconstructed ligaments by the method which was then used. In fact, this was so obvious during the course of an operation in 1931 that the operation was not completed.

Another method was, therefore, desirable to obtain a firm resistant implantation in bone, even in the presence of osteoporosis. As a result of assurance from previously successful cases that a fascial or tendinous support would maintain correction of genu recurvatum, an operation was devised to pass the transplanted tendon or fascia completely through the tibia and femur to provide a direct support for the posterior aspect of the knee (Fig. 6). The approach used for the capsuloplasty of Philip Wilson provides an adequate exposure; and the patient mentioned previously, upon whom operation had been

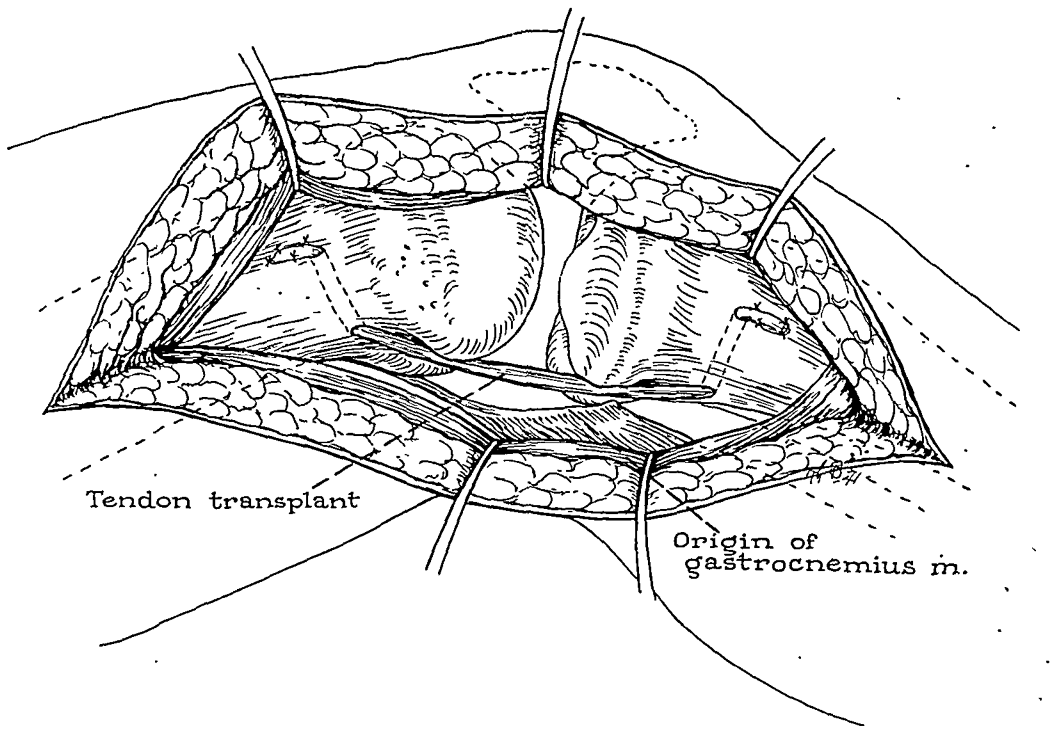

Fig. 6

Diagram of alternative operation. The peronaeus longus tendon, or a tube of fascia lata, passing through drill holes made diagonally backward through the femur and the tibia, is used to form a check ligament to prevent genu recurvatum. This provides a direct support posteriorly, but it will not correct lateral instability.

discontinued, was again operated upon three weeks later. The result was so gratifying in this and in two subsequent cases that it appears worthy of description, and is recommended as another efficient method for the construction of a check ligament to correct genu recurvatum. It has been found preferable to the original method of reconstructing the collateral ligaments in the absence of lateral instability. The deformity and stability of the knee have remained well corrected fourteen years and seven years, respectively, after operation.

The tendon of the peronaeus longus is used as the material for the check ligament. This was found by Henderson to be more efficient than a strip of fascia lata to stabilize recurrent dislocation of the shoulder, and has the added advantage of being less bulky and stronger in proportion to thickness. Probably there is no serious objection to the use of fascia lata rather than the tendon of a strong muscle.

An appropriately long portion of the peronaeus longus tendon, consisting of two-thirds of its thickness, is excised according to the technique described by Henderson. If this muscle is paralyzed, the entire tendon is utilized. It is laid aside in a moist sponge for later use. A longitudinal incision is then made over the medial aspect of the lower end of the

TABLE II

Hemostasis with Oxidized Gauze and Absorbable Gelatin in Operative Procedures on Various Bones and Joints

Case	Operative Procedure	Substance Used	Remarks
F. D. 95–130	Resection of first toe, metatarsal and cuneiform bones, and overlying inflammatory tissue for tuberculosis	Oxycel	Lesion was so extensive that it could not be closed, regardless of releasing incisions. Severe oozing was readily controlled by oxycel, used as a superficial dressing.
F. D. 95–131	Mid-calf amputation for tuberculosis of foot	Gelfoam and thrombin	Oozing well controlled. Wound closed without drainage. Skin traction applied. Wound healed by first intention.
J. J. M. 96–132	Saucerization and arthrodesis of hip for tuberculosis	Gelfoam and thrombin	Oozing well controlled. Wound closed without drainage. Healed except for stitch abscess, slight serous discharge, and two small areas of persistent granulations, on fifty-sixth day after operation.
A. B. 97–133	Evacuation of soft-tissue abscess (*Staphylococcus aureus*)	Gelfoam and thrombin	Wound closed without drainage. On the tenth day after operation, wound was healed except at its upper angle. Complete healing on the fifteenth postoperative day.
A. P. 53–102	Saucerization of femur (15-inch incision) for osteomyelitis	Oxycel	No tourniquet used. Oozing readily controlled by four pieces of oxycel, which were removed prior to closure of the wound without drainage. Wound healed on thirtieth day after operation. (See Table I, Case 53–78.)
L.	Exploration for herniated nucleus pulposus and Hibbs' spine fusion, reinforced by double clothespin bone graft	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Spontaneous evacuation of small hematoma, three weeks after operation, followed by rapid healing of wound.
S. L.	Hibbs' spine fusion for tuberculosis	Oxycel	Oozing readily controlled. Wound healed by first intention.
T. W. 14–23	Saucerization of scapula for tuberculosis	Oxycel	Oozing readily controlled. Wound closed without drainage. Spontaneous evacuation of serosanguineous fluid on the eighth postoperative day; wound failed to heal.
S. H. 88–118	Excision of greater trochanter for tuberculosis	Gelfoam and thrombin	Oozing readily controlled. Wound closed without drainage. Spontaneous evacuation of a hematoma on eleventh day after operation. Culture of wound at operation sterile. Wound failed to heal.
L. S. 91–124	Interinnomino-abdominal amputation for osteogenic sarcoma superimposed on Paget's disease of innominate bone	Gelfoam and thrombin	Troublesome oozing in perineal region and from stump of ilium readily controlled. Portion of skin flap sloughed.
M. Z. 93–127	Interinnomino-abdominal amputation for recurrent osteogenic sarcoma of stump of thigh	Oxycel, gelfoam, and thrombin	Troublesome oozing readily controlled. Wound healed by first intention except for small area of sloughing of skin flap, due to embarrassed circulation.
H. C. 117–169	Biopsy for osteogenic sarcoma of coracoid process	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Interscapulothoracic amputation seven days later. Wound healed by first intention. Specimen showed no evidence of irritation incidental to presence of oxycel.
A.	Biopsy for osteogenic sarcoma of scapula, superimposed on Paget's disease	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Specimen obtained at site of interscapulo-thoracic amputation showed no evidence of irritations due to oxycel.

is a most important consideration. Mild genu recurvatum is often advantageous in the presence of a weak quadriceps, because it gives stability to the knee. Complete correction of the recurvatum may, therefore, not be desirable when the quadriceps is paralyzed; and one should be cautious in advising operation in the presence of paralysis of the quadriceps, because ability to walk thereafter without a brace would be uncertain. Paralysis of the glutaeus maximus associated with a weak quadriceps is a contra-indication for the operation, because the backward lurching limp at the hip requires a good quadriceps to prevent the knee from giving way. The foot should be stable or should be made so. An excessive equinus deformity must be corrected, because this predisposes to strain at the back of the knee. Mild equinus, however, may be advantageous in the presence of a weak quadriceps.

SUMMARY

Either of the operations herein described is recommended when a bone deformity, consisting of a depression of the anterior articulating surface of the tibia, is not a major factor causing genu recurvatum. In this case, the operation of Brett to elevate the tibial plateau or the osteotomy of Campbell or Irwin would be required. It would seem, however, that these osteoplastic operations would not correct the lateral instability which so frequently accompanies genu recurvatum; nor will a check-ligament type of operation ensure lateral stability unless the lateral as well as the posterior structures are reinforced. The original operation to reconstruct collateral ligaments to a more posterior position on the condyles of the femur meets this requirement, and is the operation of choice when lateral instability as well as genu recurvatum is present. When there is no lateral instability of importance, the alternative operation of reinforcing the posterior structures alone is sufficient, and probably more adaptable.

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ultimate failure of healing occurred as a result of secondary infection of such a temporarily disrupted wound. One should, therefore, weigh these possibilities carefully before resorting to the use of these hemostatic agents which, under difficult circumstances, are nevertheless of inestimable value in the control of oozing and bleeding.

CONCLUSIONS

1. The use of oxidized gauze or absorbable gelatin as a vehicle for thrombin and penicillin in filling dead spaces or bone cavities appears to be inadvisable, from the authors' limited experience, because of the large proportion of complications interfering with the healing of the surgical wounds by first intention.

2. The use of oxidized gauze or absorbable gelatin with thrombin as hemostatic agents in the presence of troublesome oozing and bleeding is advisable, and at times invaluable, notwithstanding the fact that the final healing of the wound may, in a considerable proportion of instances, be delayed by temporary partial disruption incidental to the evacuation of collections of blood and serum.

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TABLE I

Treatment of Chronic Osteomyelitic Lesions, with and without the Use of Absorbable Substances to Obliterate Bone Cavities

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
7–75	Saucerization of tibia and plastic repair of skin	Oxycel	Healed by first intention. Fluctuation developed at operative site, followed by spontaneous serosanguineous discharge. Healed on forty-eighth day after operation.
10–17	Saucerization of tibia	None	Healed by first intention; serosanguineous discharge on thirteenth day after operation. Healed on thirty-fourth day.
24–35	Saucerization of femur	None	Wound failed to heal; inadequate operative procedure.
25–37	Intra-articular and extra-articular arthrodesis of hip	None	Healed by first intention.
26–40	Resection of metatarsal and toe	None	Healed by first intention.
26–160	Resection of two toes and metatarsal	None	Healed by first intention.
27–41	Saucerization of humerus	None	Healed by first intention; preoperative sinus healed on twenty-ninth day after operation.
30–46	Saucerization of tibia	None	Necrosis of skin at lower angle, due to embarrassed circulation. Healed on fiftieth postoperative day.
33–49	Saucerization of femur	None	Healed by first intention.
34–51	Saucerization of tibia	None	Healed by first intention except for area of atrophic skin; ulcer persisted.
37–54	Saucerization of humerus	None	Slight discharge of serosanguineous fluid. Healed on thirteenth day after operation.
38–55	Saucerization of tibia	None	Slight sanguineous discharge. Healed on fourteenth postoperative day, except for areas of necrosis due to embarrassed circulation. Healed on forty-fourth postoperative day.
41–59	Resection of toe and metatarsal	None	Healed by first intention.
42–60	Saucerization of tibia	None	Slight discharge; healed on twentieth day after operation.
42–61	Saucerization of neck of femur	Oxycel	Healed by first intention on tenth day. Wound moist and irritated, but remained healed.
43–62	Resection of sacro-iliac joint	None	Healed by first intention.
47–66	Saucerization of femur	None	Healed by first intention on thirteenth postoperative day, after spontaneous evacuation of a slight hematoma.
49–69	Saucerization of tibia	Oxycel	Healed by first intention after spontaneous evacuation of small hematoma.
50–73	Saucerization of disarticulated hip and plastic repair of skin	Oxycel	Failure of healing; complete excision of avascular scar not possible. Complicated by severe amyloidosis.
53–78	Saucerization of femur	Oxycel	Failure of healing; sanguineous discharge; possibly due to failure to saucerize a second focus in same femur.
54–79	Saucerization of femur	Oxycel	Considerable bleeding into dressings; wound moist; small stitch abscesses. Healed on thirty-first day after operation.
54–135	Saucerization of humerus	Gelfoam and 1,500 units of thrombin	Considerable sanguineous discharge on fifteenth day after operation. Healed on seventeenth postoperative day.

TABLE I

AVERAGE LENGTHS OF THE BONES OF THE LOWER EXTREMITY AS MEASURED FROM ORTHOROENTGENOGRAMS

Skeletal Age (*Years*)	Femur			Tibia		
	Percentile*			Percentile*		
	10th	50th	90th	10th	50th	90th
Girls						
5	24.7	26.1	27.6	19.2	20.4	21.8
6	26.7	28.2	30.2	21.0	22.4	23.8
7	28.6	30.2	32.6	22.6	24.3	25.7
8	30.6	31.9	34.6	24.0	25.2	27.3
9	32.4	34.0	36.1	25.1	26.9	28.9
10	33.4	35.6	37.7	26.0	28.2	30.5
11	35.0	37.4	40.1	27.5	29.4	32.2
12	36.3	39.2	41.9	28.8	31.0	33.7
13	38.0	41.2	43.9	30.3	32.8	35.6
14	39.5	41.8	44.4	31.0	33.0	36.2
15	40.3	42.3	44.8	31.4	33.0	36.6
16	40.1	42.3	45.4	31.2	33.6	36.9
Boys						
5	24.2	25.6	26.8	18.8	20.3	21.5
6	26.0	28.0	29.2	20.3	21.9	23.7
7	27.8	29.8	31.6	21.8	23.5	25.4
8	29.6	32.1	33.6	23.4	25.1	27.0
9	31.8	34.1	36.1	24.8	26.5	28.6
10	33.7	35.7	38.2	26.0	28.0	30.1
11	35.1	37.4	40.0	26.9	29.2	31.2
12	36.6	39.3	42.2	28.3	30.6	33.2
13	38.5	41.2	43.9	29.8	32.8	35.0
14	40.2	43.5	46.8	30.9	34.6	36.5
15	42.6	45.4	47.7	33.2	36.0	38.1
16	42.8	46.6	49.4	33.4	37.0	39.2
17	42.6	45.8	49.6	32.6	37.0	39.1
18	42.9	45.8	49.4	32.5	37.0	39.0

*If, in a group of cases, a particular measurement is distributed on the basis of size, the dimension of the individual which is larger than 90 per cent. and smaller than 10 per cent. of the cases may be said to define the ninetieth percentile for the distribution. Similarly, the "fiftieth percentile" describes the size of the middle individual (the median),—the case above and below which lie one-half the cases in the entire series. The "tenth percentile" indicates the level below which lie 10 per cent. of the measurements for the group, and above which lie 90 per cent.

It is the purpose of this communication to report a method of prediction, for use in epiphyseal arrests, which is based upon cumulative roentgenographic measurements of the femur and of the tibia in growing children. It is proposed, also, to outline the experiences with epiphyseal arrests at The Children's Hospital, Boston, regarding both the accuracy of the predicted effect and the incidence of deformities. In all references in this paper to arrest of the proximal tibial epiphysis, it is to be inferred that it is accompanied by arrest of the upper fibular epiphysis.

The chart which is presented for use in prediction must be considered a tentative one, and it will be revised as more data are accumulated. It represents a part of the

TABLE I (*Continued*)

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
94–129	Saucerization of tibia	Gelfoam and 1,500 units of thrombin	Serous discharge on thirteenth postoperative day; healed on fifteenth day. Fluctuation on twenty-second postoperative day; spontaneous serous discharge on twenty-fifth day. Healed on thirty-second day after operation.
98–136	Saucerization of radius	None	Healed by first intention.
100–38	Saucerization of tibia	None	Sanguineous discharge on sixth day after operation. Spontaneous discharge of hematoma on twentieth postoperative day. Healed on thirty-first postoperative day.
104–144	Saucerization of femur	None	Fluctuation at operative site on ninth day after operation. Wound healed without discharge.
105–145	Saucerization of tibia	Gelfoam and 1,500 units of thrombin	Spontaneous evacuation of hematoma on eighth day after operation. Healed with persistent fluctuation on thirteenth postoperative day.
105–146	Saucerization of tibia	None	Slight sanguineous discharge on sixth day after operation. Healed on seventeenth postoperative day.
106–148	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Sanguineous discharge and induration at lower angle on eighth day after operation; sinus persisted. Result: failure.
106–159	Saucerization of femur	None	Sanguineous discharge and irritation of wound on eighth day after operation. Spontaneous evacuation of hematoma on eighteenth postoperative day. Sinus persisted. Result: failure.
109–151	Saucerization of distal phalanx of finger	None	Healed by first intention.
113–158	Saucerization of tibia and plastic repair of skin	Gelfoam and 1,500 units of thrombin	Spontaneous evacuation of hematoma on sixth day after operation. Persistent discharge. Healed on fifty-ninth day after operation.
123–176	Saucerization of femur	None	Healed by first intention.

gelatin (gelfoam) [3,4,8]. These substances were left in the wound, to be absorbed eventually by the tissues. In addition, they were used as vehicles for penicillin. In some instances, gelfoam was used as a partial filler of the cavity, in conjunction with thrombin to control the oozing and with penicillin to control the infection.

The technique of the use of these substances had to be somewhat different from that described by other investigators [7,10-14], who used these substances in the presence of active oozing in soft tissues. Since the majority of the authors' patients were operated upon under tourniquet control, which was not released until after the compression bandages had been applied, the operative fields were dry. Oxycel was packed firmly into areas where bleeding was anticipated after release of the tourniquet. These sites were usually the exposed medullary canal openings and the metaphyseal areas. The wounds were then flooded with normal saline, containing 250 units of penicillin per cubic centimeter of fluid, closed without drainage, and dressed as described, before the tourniquet control was released.

Gelfoam was used under circumstances similar to those existing in the use of oxycel, and differed only in those steps inherent in the use of absorbable gelatin. Fifteen hundred

TABLE II

CENTIMETERS OF CORRECTION TO BE DERIVED FROM ARREST OF THE DISTAL FEMORAL OR THE PROXIMAL TIBIAL EPIPHYSIS
(Tentative Table, January 1947)

Skeletal Age (*Years*)	Distal Femoral Epiphysis			Proximal Tibial Epiphysis		
	Low	Average	High	Low	Average	High
			Girls			
8	6.7	7.4	8.1	4.4	4.9	5.4
9	5.4	6.1	6.8	3.4	4.0	4.5
10	4.1	4.8	5.5	2.6	3.2	3.7
11	2.8	3.5	4.2	1.7	2.3	2.8
12	1.5	2.2	2.9	0.8	1.4	1.9
13	0.2	0.9	1.6	0	0.6	1.1
14	0	0.3	0.7	0	0.1	0.3
15	0	0	0	0	0	0.1
			Boys			
10	6.1	7.1	8.1	4.0	4.7	5.4
11	4.9	5.9	6.9	3.2	3.9	4.6
12	3.7	4.7	5.7	2.4	3.1	3.8
13	2.4	3.4	4.4	1.5	2.2	2.9
14	0.8	1.8	2.8	0.6	1.3	2.0
15	0	0.7	1.7	0	0.4	1.1
16	0	0.3	0.8	0	0.1	0.4
17	0	0	0.2	0	0	0.1

form the essential data. Observations of the patients who have had epiphyseal arrests include lateral roentgenograms of the knees, taken either semiannually or annually until the time of epiphyseal closure.

DERIVATION OF THE METHOD

The method of predicting the effect of epiphyseal arrests which the authors are proposing is based upon a cumulative series of the annual increments in the growth of the long bones of the lower extremity between consecutive ages (Fig. 1). These increments have been computed separately for the femur and for the tibia, and are subdivided as to sex. Measurements were derived from three to six annual orthoroentgenograms of the normal lower extremity of each of seventy-one boys and fifty-one girls with anterior poliomyelitis, and from eight to ten consecutive yearly roentgenographic measurements of twenty boys and eighteen girls who are normal individuals. The average number of increments for each age level was thirty. The extremes are recorded in graphic form, as are the averages. In the derivation of these original average increments, to avoid criticism, only those individuals were used whose chronological ages corresponded to the skeletal ages, as evaluated by the method of Todd*.

For practical usage, curves were constructed to show how much correction might be

*Children with markedly retarded or advanced maturation were placed in a separate series, and the ages of all the individuals in this group were adjusted to conform to their skeletal ages. Yearly increments of bone lengths, derived for this series by the use of skeletal age, corresponded so closely to those for the group which was used that the two could have been combined, if skeletal age had been used for the entire distribution. This, with other evidences which will be discussed later, emphasizes the importance of the assessment of relative skeletal maturity in considerations of growth.

were encountered. Cultures of the wound at the primary and secondary operative procedures yielded *Bacillus proteus*. Another lesion (in Case 106–148) failed to heal. Subsequent reoperation without the use of an absorbable agent similarly resulted in failure of healing.

Comment

The authors readily appreciate that the six lesions in which oxycel was utilized and the eleven instances in which gelfoam was used are but a small series, from which final conclusions cannot be drawn. A comparison of these cases with those in which the absorbable substances were not used clearly indicates that the proportion of primary healing, without any complicating hematomata or other irritations of the wounds, is considerably less in the presence of these substances. The clinical difference in the character of the healing has led the authors to abandon the use of oxycel and gelfoam as fillers for bone cavities.

In this connection, Lattes and Frantz have reported animal experiments which indicate that absorbable gelatin sponge (gelfoam) showed "a slight delay in healing [of fractures] as compared with those treated with fibrin foam and with the controls, but in no case as marked as those treated with oxidized cellulose. . . . There seems to be little doubt that the presence of oxidized cellulose in the immediate vicinity of a fracture interferes with the normal processes of repair of bone." The quantities of oxycel and gelfoam used in the authors' cases were probably greater than those used by Lattes and Frantz. This may very well be an additional factor in the delay of bone repair, suggested by our series of cases.

THE USE OF ABSORBABLE SUBSTANCES AS HEMOSTATIC AGENTS IN OPERATIVE PROCEDURES ON BONES AND JOINTS

Introduction

In addition to using oxycel and gelfoam as absorbable substances to obliterate bone cavities, the authors have also utilized these substances as hemostatic agents in the presence of troublesome oozing and uncontrollable bleeding during surgical procedures on various bones and joints. The use of these substances as hemostatic agents is more in keeping with the purposes for which they have been developed and utilized by the several investigators on this subject, in contradistinction to their use as a filler for dead spaces.

Procedure

Oxycel was used in the conventional manner described by the original investigators [5,6,7,13,14]. Small pledgets of the oxidized gauze were applied by the gloved finger or by a superimposed piece of ordinary gauze, which was subsequently removed. Upon coming into contact with the bleeding area, the oxidized gauze rapidly underwent a change and became converted into a black, tarry, very friable substance which effectively controlled the oozing or bleeding. In all but a very few instances, the substance was left in place and the wounds were closed without drainage. In all instances, intramuscular penicillin was administered during the preoperative and postoperative periods, and local penicillin was used in the manner noted.

Gelfoam was used as a vehicle for thrombin and penicillin. After preparation of the substance, the pledgets were applied to the bleeding area under pressure of the gloved finger or of a superimposed piece of gauze. Difficulty was at times encountered in obtaining satisfactory packing, because of the gelatinous nature of the prepared gelfoam. All of these operative procedures were carried out under antibiotic control.

the onset of the disease. (In the patients of this series with 75 per cent. or less of musculature remaining, the average retardation of the affected extremity was 10 per cent. in the femur and 12 per cent. in the tibia.) Theoretically, mathematical formulae should be applied to correct these variants, but more data are necessary before such precise adjustments can be made. Shifting the position on the chart within the range indicated for the individual's age, according to the factors mentioned, has worked in practice. As an aid in estimating the relative bone lengths in a given child, a table is included here of the average lengths of the femur and the tibia, derived from orthoroentgenographic measurements (Table I).

The curves of prediction of the effect of epiphyseal arrest presented here do not go below the ages of eight years for girls or ten years for boys. This is an adequate age range for the correction of discrepancies in length, due to infantile paralysis. In the series under study, there have been no discrepancies greater than thirteen centimeters. Arrest at the minimum ages would effect as much correction as this; and it is doubtful whether it would be desirable to deprive an individual of more than five inches in total height in order to equalize the length of his extremities.

The chart (Fig. 2) is based upon the annual increments of growth of a normal lower extremity, rather than upon the average correction observed after epiphyseal arrest, for two reasons. In the first place, a larger group of measurements could thus be used, which gave more reliable averages and ranges in predicted values; in addition, if the corrections obtained from epiphyseal arrests were used, the figures would contain certain uncontrollable variables, which would depend upon the relative effectiveness of the epiphyseal arrest itself.

The average correction after epiphyseal arrest in this series of patients was 65 per cent. in the distal portion of the femur, and 46 per cent. in the proximal portion of the tibia. If these percentages, which are computed on the basis of the growth of the paralyzed limb, were corrected on the basis of the average coefficient of inhibition which has been observed in the paralyzed extremities, the values would be 69 per cent. of normal femoral growth and 52 per cent. of normal tibial growth. These figures are remarkably similar to the average values used in the chart of prediction—70 per cent. and 56 per cent., respectively—particularly when one considers that the figures obtained from epiphyseal arrests represent averages and, therefore, must include some cases in which an effective fusion has been slow in developing.

RELATIVE SKELETAL MATURITY AND AGE AT TIME OF EPIPHYSEAL CLOSURE

Early in this study of growth, the authors discovered that it was essential to make some sort of assessment of the relative maturity of each individual. The method proposed by Todd has been found to be the most valuable guide which exists at this time, although it has certain limitations. The importance of using skeletal age, rather than chronological age, in prediction may be illustrated by comparing the effect of femoral arrest in two girls of the same chronological age. In Case A, with a chronological age of eleven and a skeletal age of eleven, a correction of 3.0 centimeters was obtained. In Case B, with a chronological age of eleven years and four months but with a skeletal age of thirteen years and six months, only 0.9 centimeter of equalization was accomplished.

It was the authors' rule to use the skeletal age in predictions, first, if the skeletal age deviated nine months or more from the chronological age or, second, if it varied consistently in serial examinations by as much as six months.

The importance of assessment of the degree of skeletal maturity is further emphasized by considering the age at which the epiphyses of the lower extremities fuse. As judged by serial roentgenograms, this fusion occurred at an average skeletal age of fifteen years and three months in girls and of seventeen years and three months in boys. In all instances, the fusion was observed within one year of these skeletal ages, whereas the chronological

TABLE II (*Continued*)

Case	Operative Procedure	Substance Used	Remarks
R	Subtotal resection of ilium for osteomyelitis	Oxycel, gelfoam, and thrombin	Serious bleeding of superior gluteal artery occurred. Ligation impossible because of retraction of artery into sciatic notch. Bleeding partially controlled by hemostats. Packing with gelfoam proved impractical, because of its gelatinous nature. Packing with oxycel controlled the bleeding and made possible the completion of the operation.

Results

In Table II are listed all of the operative procedures in which either oxycel or gelfoam was used for the specific purpose of controlling troublesome oozing or frank bleeding. In all instances, hemostasis was satisfactorily and readily accomplished. The application of oxycel proved to be simpler and more effective than that of gelfoam. The gelatinous nature of the latter substance made firm packing difficult.

It should be further observed that, of seven instances in which oxycel alone was used as a hemostatic agent, only four wounds were found to be healed by first intention at the time of removal of the sutures. These wounds remained healed without further complications. In two of these cases, amputations were performed at the end of one week, thus shortening the period of observation of the wounds. All of the wounds in which oxidized gauze was used eventually healed satisfactorily, with the exception of two which were of a tuberculous nature. These failures cannot be attributed to the use of oxycel.

Of five instances in which gelfoam and thrombin were used as the hemostatic agent, only one healed by first intention and remained healed without any further complications. Three of the wounds eventually healed satisfactorily, subsequent to the development of complicating hematomata or skin necroses. These complications are not attributable to the use of the hemostatic agent. The fifth instance ended in failure of the wound to heal, probably as a result of the sinus formed by the hematoma and the resultant secondary infection of the wound, which at the time of operation was sterile.

In the remaining two cases presented in Table II, both oxidized gauze and absorbable gelatin and thrombin were used for the production of hemostasis. In one of these (M. Z.), a portion of the skin flap became necrotic for reasons unrelated to the use of the hemostatic agents. In the second case (R.), gelfoam proved to be ineffective in the production of hemostasis. The wound eventually broke down because of the devitalization of a portion of the bone which had been left in place.

Comment

The use of oxidized gauze or absorbable gelatin with thrombin for hemostasis, in the presence of troublesome oozing and bleeding, has proved effective in difficult circumstances. The use of oxidized gauze is simpler than the use of absorbable gelatin and thrombin. The effectiveness of gelfoam has been found to be increased by investigators [10,11,12] who have used suction to make it adhere to the bleeding area. The authors' experience is limited to the simple application of the substance to the bleeding surface, by pressure of the gloved finger or of an overlying piece of gauze, which is subsequently removed.

It is also apparent from our limited experience that the use of these substances complicates the healing of the surgical wounds in an appreciable number of instances. These complications consist in the spontaneous evacuation of accumulations of blood and serum, with resultant temporary partial disruption of the wound. In at least one instance,

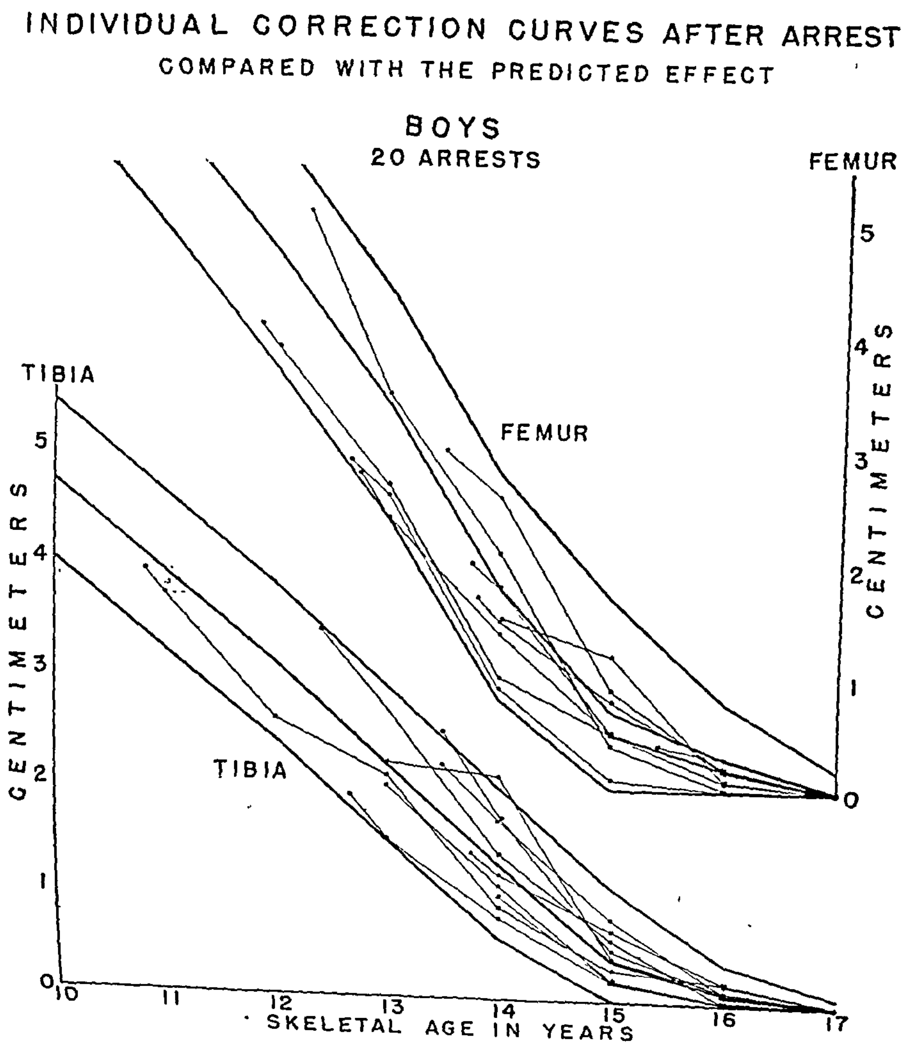

FIG. 3-A

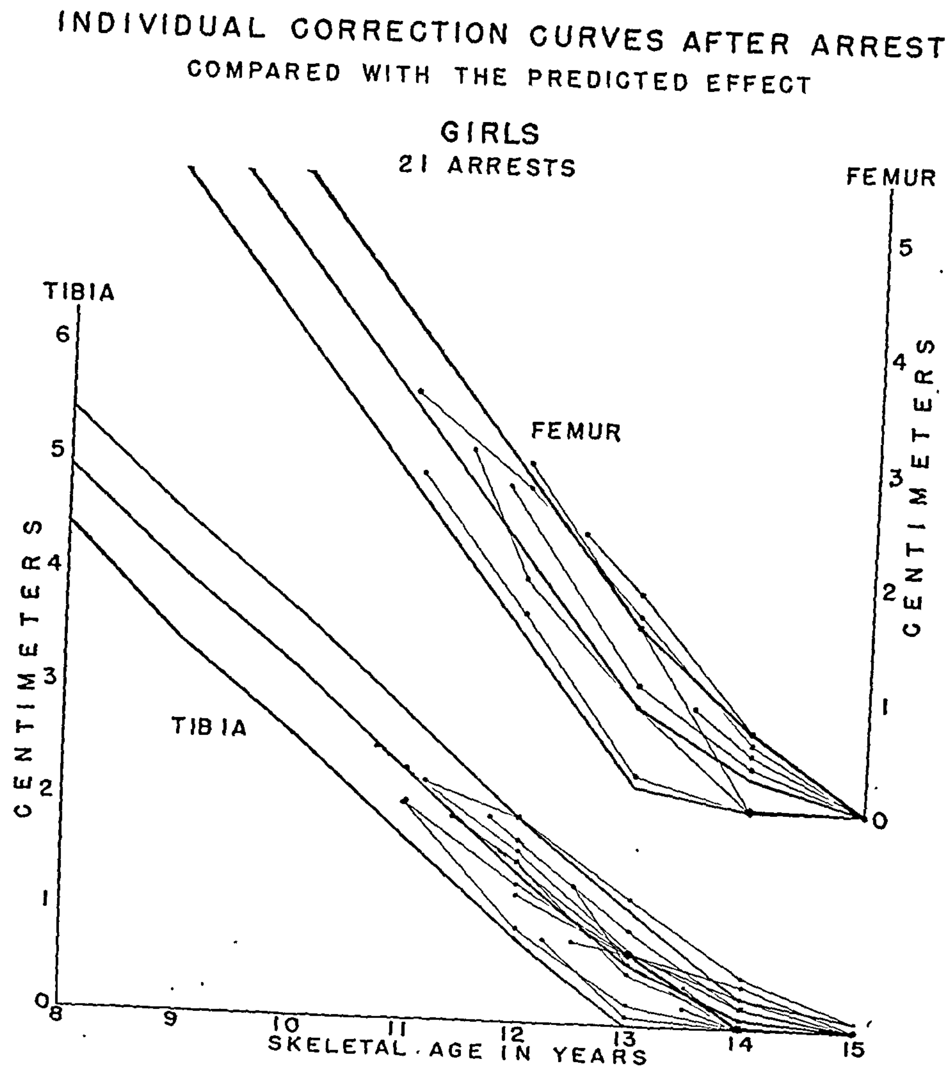

FIG. 3-B

The amounts of correction observed at consecutive skeletal-age levels, after forty-one epiphyseal arrests, follow the pattern indicated by the prediction curves.

EXPERIENCES WITH EPIPHYSEAL ARREST IN CORRECTING DISCREPANCIES IN LENGTH OF THE LOWER EXTREMITIES IN INFANTILE PARALYSIS

A Method of Predicting the Effect*†

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Discrepancy in length of the lower extremities, if it exists to any considerable degree, is disabling. In infantile paralysis, this disability is greatly exaggerated by the associated paralysis and related skeletal abnormalities; so that measures to equalize the length of the extremities take on added importance.

When growth is complete, the only procedures available are direct lengthening or shortening of one of the long bones. In the growing child, however, the possibility occurs of modifying growth. The ideal arrangement would be to stimulate the growth of the shorter limb. Since no feasible method of accomplishing this exists at present, measures designed to inhibit the growth of the longer limb must be chosen. Surgical epiphyseal arrest, or epiphyseodesis, was first described by Phemister in 1933. This has proved to be a practical method of inhibiting growth, although deformities occurring after the procedure in certain instances have been described by Straub, Thompson, and Wilson, and by Regan and Chatterton. Roentgen irradiation has been shown to inhibit the growth of the epiphyses [2, 3, 4]. Although the use of such a means to affect growth in the child was proposed by Judy, it remains to be demonstrated that undesirable effects do not arise from the irradiation and that its action on growth can be well controlled.

The important problem in surgical arrest is to choose the site of the procedure at the particular age which will allow equalization in length. This necessitates an ability to predict, within a practical amount, the growth in the lower extremity which will occur from various ages until maturity, as well as to estimate the proportion of growth which will be inhibited by the arrest. Although the procedure itself inhibits the growth of the longer limb, the index of its effect on the relative lengths of the extremities is based upon the growth of the shorter extremity.

Various techniques of predicting growth have been proposed. Hatcher adapted the Baldwin tables to obtain a derived length of the extremity[5], and used a percentage from each epiphysis, as described originally by Digby. Gill and Abbott described a more complex method, which was likewise based upon a derived length for the extremity. They emphasized the importance of using skeletal rather than chronological ages in prediction. White and his associates suggested a simplified method, in which they proposed that the obliteration of either the upper tibial or the lower femoral epiphysis resulted in a loss in growth of one-quarter inch to three-eighths of an inch per year, with the assumption that growth terminated at the age of sixteen in girls and at seventeen in boys.

No method, however, has been based upon actual measured lengths of the femur and of the tibia; in fact, the authors are unable to locate published curves of growth of the femur and tibia, through the period of maturation, other than those which they presented recently[1] (Table I).

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1947.

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by subtracting the age of the individual under consideration from thirteen and three-quarters years for girls and from fifteen and three-quarters years for boys, in order to obtain the number of years of growth on the basis of the full yearly increment. The figure so obtained is multiplied by the average increment of growth for the particular bone. In a boy ten and three-quarters years of age, for example, the formula for the effect of a femoral arrest would be as follows: $1.3 \times (15\frac{3}{4} - 10\frac{3}{4}) = 6.5$ centimeters.

To determine the indicated age for an arrest in a particular individual, one takes the amount of shortening in centimeters, divides this figure by the yearly increment of the femur (1.3), the tibia (0.9), or the combination of the two (2.2), as indicated, to ascertain the number of years required for the equalization. This figure is then subtracted from the age of thirteen and three-quarters years in girls or fifteen and three-quarters years in boys, to determine the age at which the arrest is indicated. The method has various defects, chief of which is that not enough data have been collected to indicate the range of individual variation in increments. It was, however, the second most accurate method when applied to the cases in this series, and does allow a prediction when no chart is available.

TABLE III

Final Results Compared with the Predicted Effect

		No. of Arrests	Per Cent.
Result within one-half inch of predicted amount		54	88.5
Result one-half inch or more above average prediction		1	1.7
Result one-half inch or more below average prediction		6	9.8
Delayed operative effect	4		
Other (one case)	2		
Total arrests with adequate measurements		61	100.0

The chart (Fig. 2) provided the most accurate prediction for the forty-one cases of arrest in this series which were available for the test (Fig. 4). It may be well to comment again that these cases were not included in the construction of the original table. In none of the uncomplicated cases in the test series did the outcome vary as much as 1.2 centimeters (one-half inch) from the average value predicted; in a larger group, to be discussed later, however, there were six individuals in whom a greater deviation occurred.

This chart has the advantage of providing a single graph which may be used directly, without mathematical computation. Moreover, it provides a range within which an individual may be placed, after consideration has been given to the various factors which might modify the expected amount of correction.

RESULTS OF EPIPHYSEAL ARRESTS

The clinical results of epiphyseal arrest in cases of infantile paralysis were evaluated in all patients in whom growth was complete and in whom observations existed before and after operation. Falling into this category were seventy-seven arrests, representing fifty cases; forty-one of the seventy-seven were in the test group discussed previously. The operations did not follow a constant technique, and the procedures were carried out by many different surgeons. Thirteen of the operations were done at other hospitals. All of the patients were available for evaluation of deformities and complications; in sixteen arrests, however, the measurements were inadequate to compare the amount of correction obtained with the result which had been predicted. These were mainly the cases in which teleoroentgenograms had been used for the early measurements.

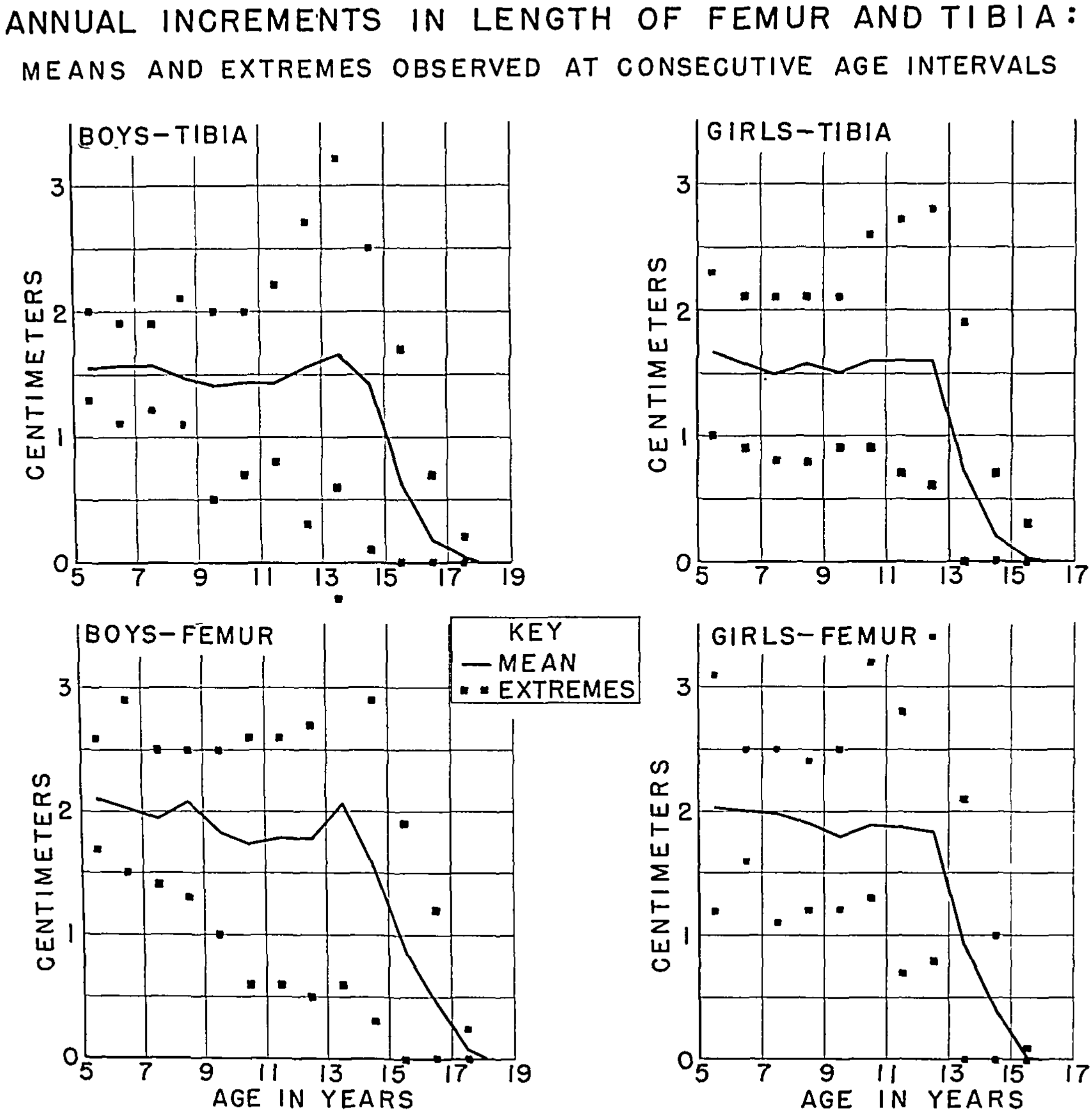

FIG. 1

These values for the annual increments of the bones of the lower extremity constitute the basic data from which the prediction curves were derived. All measurements were made from orthoroentgenograms, which give the true lengths of the bones.

material from a study of growth which has been in progress since 1940. This study involves approximately 700 children, 87 per cent. of whom have residual paralysis in one lower extremity with a normal extremity on the other side; and it also includes observations on 158 normal children, who are the subject of study in the Department of Maternal and Child Health, Harvard School of Public Health.

Studies of growth should be longitudinal,—that is, they should follow the same individual throughout the period of growth, until maturity. The present study follows this principle. However, a sufficient time has not elapsed for the tables to be constructed from completely longitudinal data; and the report represents a combination of limited longitudinal observations of the various children.

The study includes various measurements of the children, performed at regular intervals. Orthoroentgenograms of the femur and of the tibia of each child are taken at yearly intervals; in certain cases they are taken as often as once every three months. This technique of roentgenographic measurement has been described by Green, Wyatt, and Anderson, and is accurate enough to allow the recording of such quarterly increments of growth. For the purposes of this report, the lengths of the bones, as measured roentgenographically,

CORRECTION OBTAINED

Not all cases adhered as closely to the prediction graph as did those used in the evaluation of the method. Of the sixty-one arrests which could be evaluated, the result was below the range predicted in ten; and in five the result obtained was above the range of prediction (Fig. 5). However, the discrepancy was small in most of these. In only seven arrests, represented by six cases, was the deviation as much as 1.2 centimeters from the average prediction; in six of these, the correction was less than that predicted; in one, the correction was 1.3 centimeters greater than the average prediction (Table III). The six arrests in which the result was less than that predicted showed a mean discrepancy from the average prediction curve of 1.8 centimeters, although one arrest which was technically ineffective deviated by 3.3 centimeters.

Deviations from the estimated amount seemed to be due primarily to two causes,—either an arrest which was not immediately effective on a technical basis, or an individual with marked irregularity of maturation, as judged by skeletal age. Secondary considerations were a patient with either very short extremities and a small increment of growth, or very long extremities and a very large increment of growth; and an arrest in a patient who showed marked inhibition of growth in a paralyzed extremity.

In four of the six arrests in which the correction was significantly less than had been predicted, the procedure was not effective for quite a long time after the operation. Examination of serial roentgenograms showed that these epiphyses remained open for a longer interval than normal. The slowness of the effect could be traced more or less directly to the operative technique, including instances in which bone grafts were inserted without drilling or curettage of the epiphyseal line.

For example, one boy had a tibial arrest performed at a skeletal age of eleven years, in order to equalize a two-inch discrepancy. The average predicted effect was 3.9 centimeters, with a possible range on the chart of from 3.2 to 4.6 centimeters. However, the epiphyseal line remained open for an abnormally long time, and did not become fused until two years after the operation. The growth of the arrested tibia was inhibited only

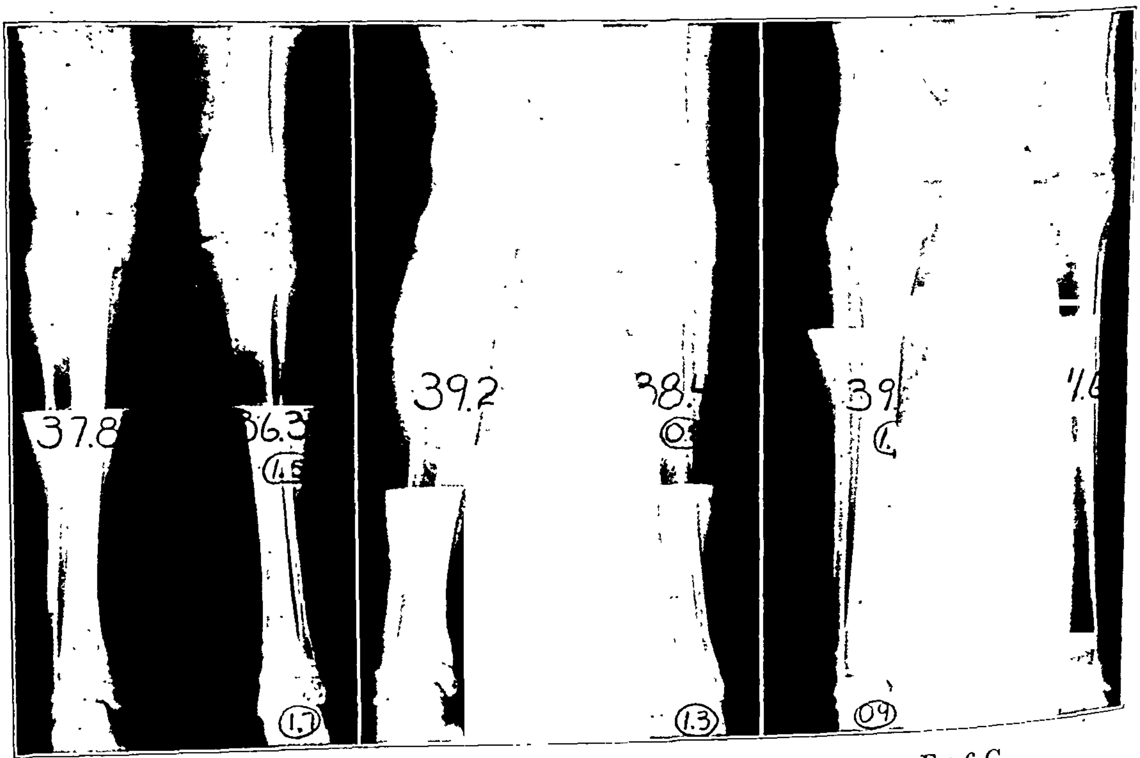

FIG. 6-A FIG. 6-B FIG 6-C

Fig. 6-A: W. B. had a tibial arrest at a skeletal age of twelve years and three months; genu valgum

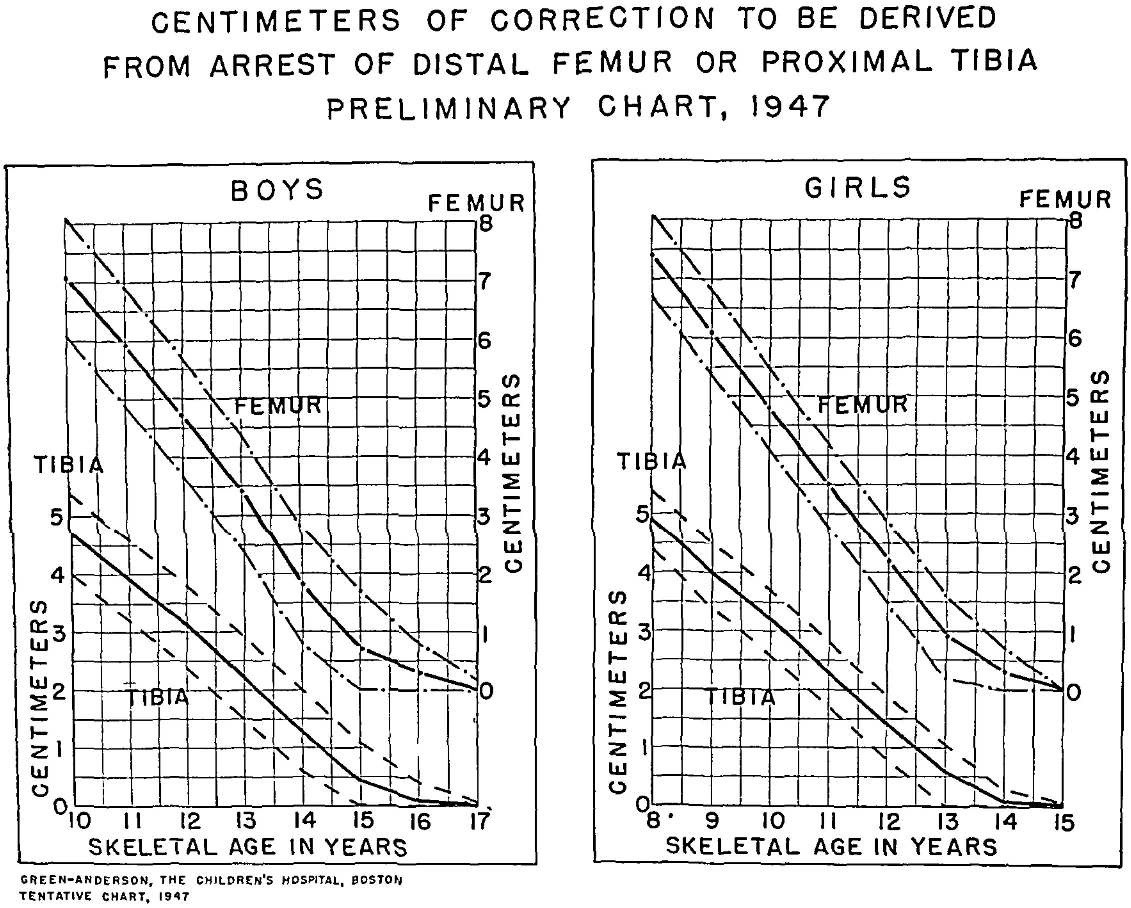

FIG. 2

The amount of growth to be eliminated after epiphyseal arrest can be estimated from this chart. The central line represents the average correction; the secondary lines, the useful range. The extremes are not indicated.

expected at each age from an arrest of either the lower femoral or the upper tibial epiphysis (Fig. 2 and Table II). The proportion of growth of the femur assigned to the lower femoral epiphysis was 70 per cent.; the upper tibial epiphysis was assigned 56 per cent. of tibial growth. These were the averages obtained from a small number of cases which had measurable transverse lines of temporary growth disturbance evident at the ends of the bones. These percentages correspond closely to the original figures of Digby, and to the amounts proposed by others. The prediction chart (Fig. 2) represents a product of the cumulative average annual increments of growth derived from a particular bone and the percentage which the specific epiphysis contributes to growth. The dense central line represents the average correction to be expected from an epiphyseal arrest at the corresponding skeletal age on the chart; a derived range is also indicated for each age level*.

In the use of the chart, various factors can modify the position between the ranges, which will be chosen as the amount predicted for a particular individual. A tall person with long legs, for example, should approach the upper limit of the predicted amount; a short individual, the lower range. Likewise, an individual with a high percentage of inhibited growth in the affected lower extremity would be expected to receive less correction than one whose coefficient of inhibited growth is less; and, therefore, the predicted amount will be adjusted toward the lower figure for the age. When a patient has not had accurate measurements long enough for the percentage of retarded growth to be determined, it may be approximated by relating the existing shortening to the estimated growth since

*Because no case in this series has yet been observed over the entire age range covered by the chart, it is impossible at this time to present actual values for the extremes. An artificial range of predictions is, therefore, included, which has been derived from the standard deviations computed at each annual interval.

TABLE IV

COMPLICATIONS FOLLOWING EPIPHYSEAL ARRESTS

		No. of Arrests	Per Cent.
Total arrests (50 cases with growth complete)		77	100.0
Tibia	43		
Femur	34		
Deformities (all in tibia)		5	6.5
Valgus	4		
Varus with genu recurvatum	1		
Osteomyelitis		1	1.3
Peroneal palsy (temporary)		1	1.3
Overcorrection of discrepancy		3	3.9

growth on the paralyzed side after operation. The interpretation was complicated by the fact that the patient had had a lumbar sympathectomy on the side of the short limb.

A patient who obtained more than the average predicted correction illustrates certain difficulties. Arrests of the upper tibial and fibular epiphyses were performed on a girl at the age of eleven years and three months, and a femoral arrest was carried out at the age of twelve years. Her skeletal age at these times was normal. The average predicted result for the two procedures was 4.3 centimeters, and the maximum was 5.6 centimeters. There was no reason to anticipate a deviation from the average prediction, since the patient was a child of average height and with only moderate involvement of the weak limb. After the arrests, however, she exhibited slowing of maturation, as judged by roentgenograms of her wrist; so that she grew for a longer period than was anticipated, and her shortening threatened to become overcorrected. A femoral arrest was performed on the paralyzed extremity at the age of thirteen, to make sure that the overcorrection would not be excessive. Examination, after growth was complete, showed that the bones of the extremity with the residual paralysis were 1.2 centimeters longer than those on the other side; but her limb lengths to the sole were equal, and her balance was symmetrical.

In two other cases the discrepancies were overcorrected, and in one a femoral arrest was performed on the opposite side to prevent further increase in length; however, the correction obtained in both instances was close to that predicted by the chart, and the error arose from choosing too early an age for operation (Table IV).

DEFORMITIES

Deformities following epiphyseal arrest have been reported by others. Straub, Thompson, and Wilson reported that, in 10 per cent. of their cases, deformities developed which were severe enough to require corrective operations. Regan and Chatterton described significant deformities in 11 per cent. of their patients.

In this series, five instances of deformities were observed in seventy-seven operations, and all followed tibiofibular arrests (Table IV). A valgus deformity was present in four; the other showed varus with associated genu recurvatum. Three of these patients have had osteotomies to correct the abnormality; following these, the final result was evaluated as good. In one, an osteotomy has been recommended; and in the other, the deformity is so slight that it does not warrant correction (Table V).

One of these patients (W.B.) showed almost immediate postoperative evidence of a developing deformity, because the operation for technical reasons failed to stop growth on the medial side (Figs. 6-A to 6-F, inclusive). A rearrest should have been performed before the deformity had progressed to the stage at which an osteotomy was needed. However, this boy exhibited increasing deformity for eighteen months, at which time a

age at which epiphyseal fusion occurred varied tremendously, covering a range of four or five years. Very little growth occurred during the year preceding the closure of the epiphyses, so that the skeletal ages of fourteen years and three months in girls and sixteen years and three months in boys can, for practical purposes, be used as the ages at which growth of the lower extremities terminates.

ACCURACY OF PREDICTION

Although the effect of epiphyseal arrest in correcting discrepancy can be determined once growth is complete, not all cases in this category can be used in testing the accuracy of methods of prediction.

Seventy-seven cases of epiphyseal arrest in this group have been followed through the period of completion of growth in the lower extremities; however, for the purpose of evaluating predictions, it was necessary to omit cases in which accurate serial roentgenographic measurements were not available, those in which the skeletal age was not recorded at the time of the procedure, and individuals in whom other operations complicated the measurements. Likewise, patients were omitted in whom the paralytic involvement was bilateral; those in whom the epiphyseal arrest was definitely slow in producing its effect, as determined by postoperative roentgenograms; and those in whom a postoperative deformity occurred.

Satisfying the demands were forty-one arrests, performed on twenty-nine patients. The other arrests were used in evaluating the result of the procedure, but not in evaluating the method of prediction. The general pattern of the action of the arrest in each of these forty-one operations was nearly always parallel to the predicted curve (Figs. 3-A and 3-B). Of the 190 points representing levels of prediction at the various ages, only 4 per cent. were outside the indicated range, and in those the deviations were of minor degree.

The accuracy of this method of prediction was compared with that of four other methods of estimating the effect of epiphyseal arrest:

1. The Baldwin-Hatcher table, assuming that the distal portion of the femur contributes 40 per cent. and the proximal portion of the tibia 27 per cent. of the growth in the lower extremity.
2. The Gill-Abbott method.
3. White's method, assuming that the distal portion of the femur contributes three-eighths of an inch per year and the proximal portion of the tibia contributes one-quarter inch per year until the age of sixteen years in girls and of seventeen years in boys.
4. A method utilizing a fixed yearly increment of growth and skeletal age.

The fourth method might be considered a modification of the method of White, and will be described in detail. In all instances, except the original method of White, skeletal ages rather than chronological ages were used (Fig. 4).

The Baldwin-Hatcher table gave a high figure for the predicted result in the boys in this series, but the girls in the group obtained corrections quite similar to those predicted. When this method was employed, in conjunction with a correction for skeletal age, predictions were more accurate than one would anticipate, when it is considered that the table is derived from anthropometric measurements. Baldwin's measurements, which were used by Hatcher, indicate that extremities grow more rapidly in boys than in girls; the authors' data, on the other hand, indicate that boys grow at essentially the same rate, but continue to grow two years longer than girls.

The Gill-Abbott method, although more complicated, has the virtue of being the only one in which the height of the individual is taken into consideration. Their predictions coincided very well with the results obtained in the authors' cases, with the exception of boys' femora, in which the amount predicted exceeded greatly that which was obtained in this series.

White's method has the great advantage that predictions are made without a chart;

diaphysis, are then inserted into the obliterated plate so as to fill it in as completely as possible. Particular care is observed, when drilling the femoral epiphysis in the direction of the patellar groove and when drilling both bones directly posteriorly, not to go beyond the confines of the bone; the drilling of the posterior portion, however, should be thorough. The graft is rotated 180 degrees and reinserted so that cortical bone impinges upon cortical bone, with the graft fitting snugly and smoothly. This fit is facilitated by the use of matched osteotomes in pairs, when the graft is removed. The periosteum is reconstructed.

If this technique is followed carefully, postoperative deformity should be minimum, and arrest should be effective from the start.

COMMENT

It is well to recall that absolute equalization of length is not the goal in all cases. A patient who must wear a long brace with a locked knee joint, for example, is usually better with one or two centimeters of shortening on the side of the brace. Each problem should be considered individually.

For those who do not need a long brace, it is desirable for the extremities to approach equality of length. Procedures to correct discrepancy are particularly indicated when marked shortening exists in patients who do not require a brace.

To determine the degree of correction which is needed, the amount of lift required to restore balance in the standing position is the important consideration, and should be evaluated. Roentgenographic measurement of the bones and clinical measurements from the anterior superior spine of the ilium to the medial malleolus and to the sole should be recorded. The decision as to the amount of arrest needed arises from a combination of these evaluations. If a triple arthrodesis is planned for a later date, it is well to add one centimeter to the amount which is considered necessary, since this operative procedure reduces the height of the foot.

In planning the correction of a discrepancy of considerable degree, it is well not to wait until the age at which arrests of both the femoral and tibial epiphyses are indicated, but to perform one operation at a younger age and the other at the age when it is needed to complete the equalization. In this way less error will occur if, for some reason, such as a change in the pattern of maturation, the original prediction should not be accurate. Marked shortening of the leg (tibia) in girls is not desirable cosmetically.

In following the condition of patients who have asymmetrical involvement of the lower extremities, caused by infantile paralysis, not only the discrepancy, but the actual lengths of the extremities should be recorded at regular intervals. Highly desirable, but not essential, are accurate roentgenographic measurements at yearly intervals. Such information permits a calculation of the percentage of inhibited growth, as well as a record of the shortening and the length of the extremities. At intervals of a year or six months, roentgenograms of the wrist for evaluation of skeletal maturity are desirable. The evaluation of skeletal age by a single determination is very much less reliable than by serial examinations.

Finally, it must be stated again that the chart which has been presented is a tentative guide for the estimation of the effect of epiphyseal arrest, and not an absolute index. The irregularity of patterns of growth must be appreciated and considered as a limiting factor in any method.

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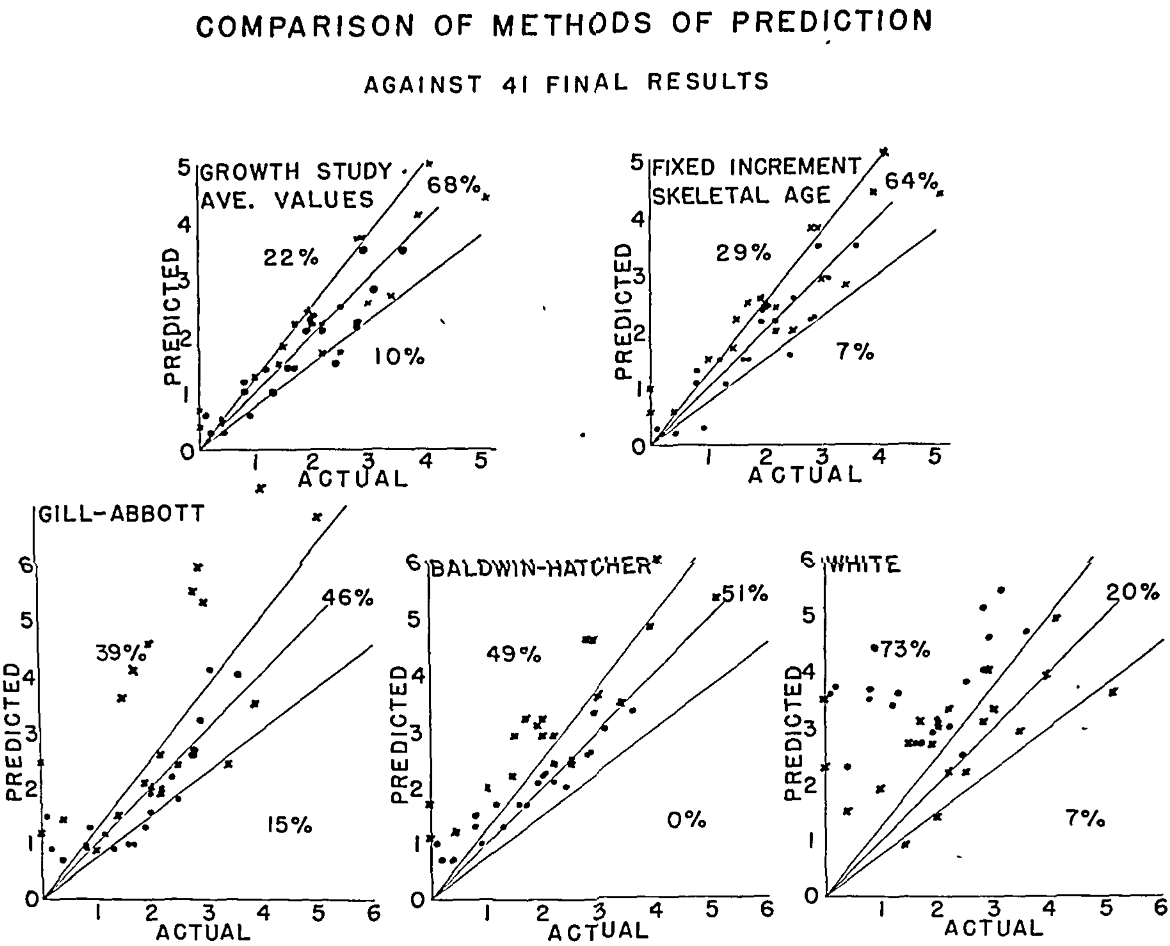

FIG. 4

Each of these charts has been constructed with a diagonal line, indicating perfect agreement between actual and predicted results; and with two other lines, spaced so as to include all cases within a 25 per cent. error of prediction. Arrests on boys are indicated by a cross; on girls, by a solid circle.

The forty-one final results in the test series corresponded more closely to the values from the authors' prediction chart (growth study, average values) than to those of the other methods.

but, on the basis of the cases tested, it was less accurate than the other methods. However, the amounts of yearly growth which White described as occurring at the epiphyses did not show great variations from those observed in the authors' cases. The inaccuracy arises largely from the fact that relative skeletal maturity is not considered, and that the ages which White used as indicating the cessation of growth could not be corroborated.

If various modifications are made in the method described by White, a technique is evolved which, as applied to the authors' cases, was quite accurate. This may be called the "fixed increment-skeletal age" method. The value used in prediction represents fundamentally a product of a fixed increment of growth, assigned to the particular epiphysis under consideration, and the number of years of growth remaining.

All computations are made with a correction for skeletal age, the ages of fourteen years and three months for girls and sixteen years and three months for boys being used as the times when growth in the extremities terminates. The yearly increments used are the average amounts which were observed in normal lower extremities of boys and girls in this series during the years of active growth. These are 1.3 centimeters for the distal femoral epiphysis and 0.9 centimeter for the proximal tibial epiphysis, except during the last year of growth, when the amount is approximately half these figures. To allow for this reduced growth in the terminal period, the figures are adjusted, for purposes of computation, as though the full increment were followed for a period of one-half year less than the actual period of growth. The effect of an arrest at a given age may then be approximated

THE POSTEROLATERAL APPROACH TO THE FEMUR

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Reparative surgery of battle fractures has proved the value of the posterolateral approach to the femur. This approach was employed originally at the suggestion of Major Champ Lyons, in order to establish adequate dependent surgical drainage of the hematoma and of the infection complicating the femoral fracture, while the patient was on his back in traction and penicillin therapy was being used. The true posterior incision was considered to be contra-indicated, because of the possibility that sinuses, forming in the wound of incision, might result in involvement of the sciatic nerve.[1] The posterolateral incision was also indicated, whenever possible, in the débridement of wounds associated with fractures of the femur, in order to allow dependent drainage while the patient was being transported in a plaster spica from the Evacuation Hospital to the Base Hospital. Because of its many advantages and because of the fact that reduction and internal fixation could be accomplished easily and rapidly by a surgeon with the assistance of only one nurse, it soon became the incision of choice in both compound and simple fractures.

OPERATION

Position of the Patient: In the author's experience, the most satisfactory position for the patient is on the back with the lower extremity suspended by a Kirschner wire in the position of 90–90–90 traction, as described by Obletz, to a frame designed by Godfrey[3]. By this means, traction of the femur and reduction of the fracture are easily accomplished, with little exertion on the part of the surgeon or his assistants. The position relaxes the hamstring muscles by flexion of the knee, and also relaxes the sartorius and rectus femoris by flexion of the hip. Moreover, the upper end of the femur is brought down from beneath the glutaeus maximus by flexion of the hip, giving more extensive exposure. If such suspension is not possible, however, the patient may be turned slightly on the unaffected side or, easier still, placed on the abdomen with the limb draped so as to allow flexion of the knee.

Incision: The line of incision is from a point just proximal to the gluteal fold, halfway between the greater trochanter of the femur and the tuberosity of the ischium, to a point just proximal to the lateral condyle of the femur, between the tendon of the biceps femoris and the iliotibial band (Fig. 1). Along this line the sulcus between the biceps femoris and the vastus lateralis can easily be palpated, so that there need be no doubt as to the exact location of the incision. Any part of this line, or all of it, may be used for the incision, depending upon the exposure required. After the superficial vessels have been ligated, the deep fascia is sharply incised. The vastus lateralis is then bluntly separated from the biceps femoris along the fascial plane. In the middle third of the thigh, some care must be taken not to separate the long head of the biceps femoris from the short head of this muscle, which brings one in close proximity to the sciatic nerve and directly over the profunda artery and vein (see *Middle Thigh*, Fig. 1). In the middle third of the thigh, the second perforating branches of the profunda femoris artery and vein are encountered, passing transversely from the biceps femoris to the vastus lateralis. These may be retracted or, if necessary, divided and ligated. As the femur is approached, it is necessary to divide the thin origin of the vastus lateralis from the linea aspera. This is the only muscle cutting necessitated by the approach, and it is seldom associated with any bleeding. The femur and the fracture site are then exposed by incising and elevating the periosteum. After the

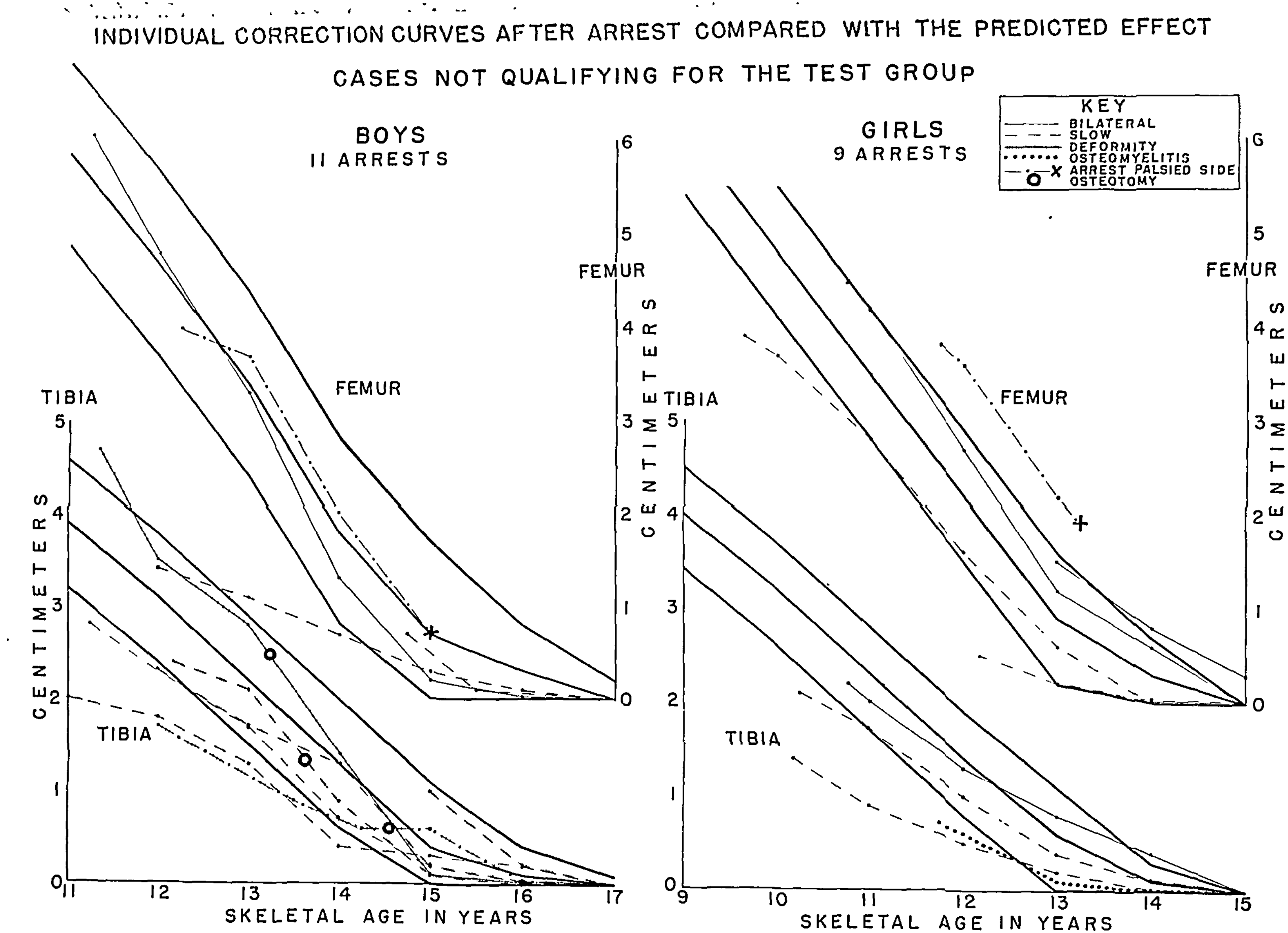

Fig. 5

The results of these twenty arrests could be measured adequately, but could not be used to test the methods of prediction because, for the various reasons indicated, they comprised an abnormal series.

in cases with marked soft-tissue loss anteriorly, which made closure of the anterior wound impossible. Drainage of infections of the anterior quadrants of the thigh, especially of the medial quadrant, was unsatisfactory when this incision was used; and other means were required. After operation, the muscles were found to fall back together, as did the skin, so that small non-disabling scars were obtained even when the incisions were not sutured. Muscle scars or adhesions which limited the motion of the knee were not encountered, although the cases could not be followed sufficiently long to be certain of this. Sensory changes were minimum, as the incision lies between the skin areas supplied by the lateral femoral cutaneous nerve and the posterior femoral cutaneous nerve.

SUMMARY

The posterolateral approach to the femur gives easy anatomical access to the enti shaft of the bone with negligible blood loss, minimum muscle damage, and only slight, any, circulatory or sensory impairment. It facilitates reduction, alignment, and fixatic of the fracture, and allows for dependent drainage. The scar resulting from the incision neither disabling nor disfiguring.

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DISCUSSION

WILLIAM T. GREEN AND MARGARET ANDERSON

(Continued from page 675)

of the whole group, however, the effect from epiphyseal arrest, performed by many different surgeons in the hospital, was within one-half inch of the prediction. Most of the variations from the predicted effect were traced to the technique of the operation.

The details of the operative technique are most important, and the reason that many are critical of the procedure is that the operation is not performed satisfactorily. A poor arrest may not obtain the predicted effect because it does not slow down growth immediately; an arrest which is done poorly on one side will produce deformity. I think that epiphyseal arrest is a good procedure, and that it is the best way to equalize the length of the extremities of the growing child in most instances.

As regards Dr. White's question, I think we should appreciate that accuracy in prediction of skeletal maturity is essential, and that we still have difficulty with it. Particularly do we have trouble with those unusual children who show variations in their patterns of maturation. For example, a child may seem by roentgenographic evaluation to be retarded in skeletal maturation at a particular period, but subsequently he shows very rapid maturation, which changes the relative position of the skeletal to the chronological age. This child, therefore, grows for a shorter period than was anticipated, and thus the effect of an arrest will be less than that predicted. Problems likewise arise with those who seem to mark time in their skeletal maturation, with the result that they grow for a longer period than was anticipated. We hope to know more about this irregularity in the velocity of maturation as time goes on.

developed, requiring osteotomy. Roentgenogram, taken one month after arrest, shows the tibial epiphyseal line to be open only on the medial side.

Fig. 6-B: Roentgenogram, taken twelve months after the arrest, shows marked genu valgum.

Fig. 6-C: Shows correction after osteotomy.

Fig. 6-D: Preoperative photograph shows the two-inch shortening.

Fig. 6-E: The degree of knock-knee prior to osteotomy is shown.

Fig. 6-F: Photograph after osteotomy shows the good contour of the extremity. The final correction in discrepancy amounted to 3.4 centimeters.

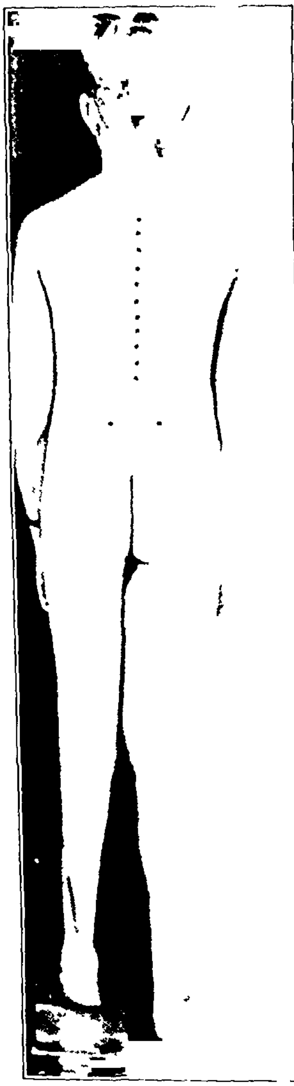

Fig. 6-D

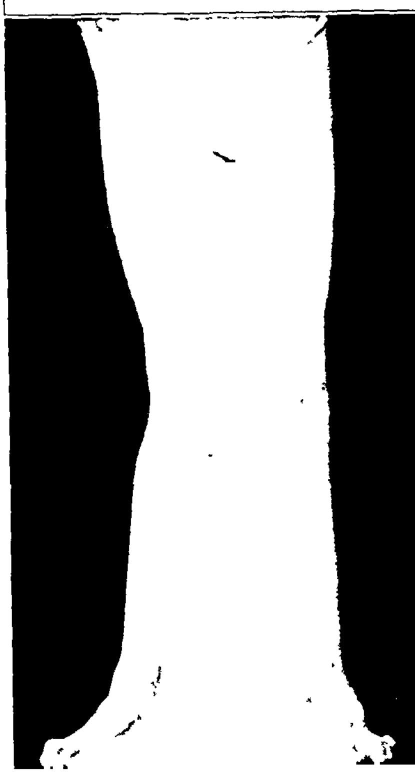

Fig. 6-E

Fig. 6-F

26 per cent. during this period, instead of an average of 46 per cent.; and a femoral arrest was necessary. The total correction from the tibial arrest was only 1.9 centimeters; but the extremities were of equal length at maturity, because the femoral arrest was normally effective.

Two other arrests which were slow occurred in one patient, a girl, and were very unusual. The tibial arrest was performed at the age of ten years, and the femoral arrest at twelve years of age. The skeletal age was normal at these times. Both epiphyses closed promptly. The coefficient of inhibited growth in the paralyzed extremity prior to operation was only 14 per cent., which is close to the average figure for this series of cases; yet the result obtained in this patient showed the greatest deviation from the predicted result. She was a very short girl at all ages; her height was just above the tenth percentile*; and the tibia on the paralyzed side grew only 4.4 centimeters after the tibial arrest rather than the average increment of 6.7 centimeters. The effect was further reduced by the fact that the percentage of growth inhibited by the procedure was less than it should have been. A full explanation of the slowness was not apparent. In part, it occurred because of her short stature and lack of growth and because of an increase in the velocity of maturation after the arrest, but some other factor contributed to the unusual result. It seems likely that, for some unknown reason, there was an increase in the coefficient of inhibited

* See footnote to Table I.

complete dislocation of the knee, when immobilization in plaster is used as treatment: "The interesting fact is that, in spite of the extensive rupture of ligaments, including the crucial ligaments, the functional results in recorded cases have been so good. The explanation of this is that the lesion is so formidable that prolonged fixation is absolutely necessary; early use and movement is impossible without displacement occurring. Hence torn structures are usually given time to unite firmly, and with exercise and use, considerable freedom of movement is recovered in time. . . . The great lesson seems to be that if the displacement is reduced and the limb fixed in a straight position, nature will do surprisingly well."

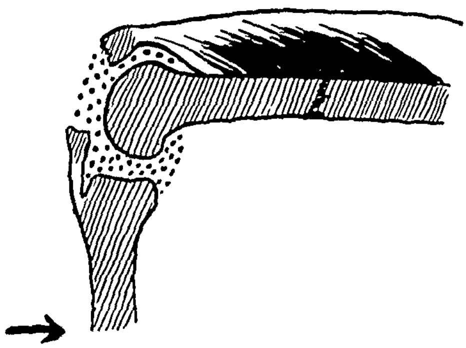

FIG. 3

Illustrating the significance of fracture of the patella, which may occur if violent flexion force is applied to a stiff knee after a fracture of the femur. The "master adhesions" in the extensor apparatus must offer greater resistance to flexion than the intra-articular adhesions, which are readily overcome, once the extensor expansion has ruptured.

3. Fracture of the Patella During Manipulation

In patients who have had fractured femora in the past, it is well known that the patella may be fractured by violent manipulation of the stiff knee. This would seem to indicate two facts,—first, the existence of "master adhesions" lying proximal to the patella, and, second, that the adhesions within the joint are less formidable, because they can be overcome with comparative ease once the knee has been disconnected from the thigh by the rupture of the extensor mechanism.

4. Results of Plastic Operations on the Quadriceps

Excellent results have been described following the excision of the adherent vastus intermedius described by Thompson. The operation offers a good possibility of securing 90 degrees of motion in knees which before operation were very stiff. The procedure is often combined with lateral and medial incisions of the capsule of the knee joint. After division of these extra-capsular structures, the knee can be flexed with the application of only moderate force, whereas before operation it may have resisted very powerful force.

5. Results of Plating Operations

In general, after internal fixation of fractures of the femur by means of metallic plates, prognosis for knee movement is not encouraging. Most surgeons attribute this to adherence of the quadriceps in the vicinity of the plate.

EVIDENCE FOR INTRA-ARTICULAR ADHESIONS

1. Direct Evidence at Operation

Arthrotomy is not often performed on stiff knees following old fractures of the femur, but it would appear, from discussion with surgeons who have had this opportunity, that intra-articular adhesions can be demonstrated. However, as already pointed out, it is possible that these intra-articular adhesions may be of secondary importance to more formidable adhesions already existing in the quadriceps.

2. Coincidental Injuries to the Knee

The knee joint often shows effusion following fracture of the femur. This is taken to indicate that the knee suffered injury at the same time as the femur; but, as already stated, even severe ligamentous injuries do not necessarily result in a stiff knee. Experimental work with animals does not suggest that intra-articular adhesions are common after prolonged fixation of normal joints [6].

CONSIDERATION OF EVIDENCE FOR THE CAUSES OF STIFFNESS IN THE KNEE

From this evidence, there would seem to be a stronger case for finding the primary site of adhesions in the vastus intermedius than within the knee joint.

It would seem reasonable, therefore, to suppose that intra-articular adhesions result from the prolonged fixation imposed by "master adhesions" within the quadriceps.

TABLE V

SECONDARY OPERATIONS AFTER SEVENTY-SEVEN ARRESTS

		No.	Per Cent.
For deformities:			
Osteotomy		4	5.2
Done	3		
Advised	1		
Secondary arrest		1	1.3
For overcorrection:			
Femoral arrest in paralyzed lower extremity		2	2.6

wedge osteotomy was performed to correct the genu valgum. Following this, no further increase in the deformity occurred, and the final result was a limb of good contour with very little discrepancy in length.

In an analysis of the causes of deformity and the delay in effect of the arrest, the postoperative roentgenograms usually are a clue to the difficulty. Persistent asymmetry in the width of the epiphyseal line or failure of the line to become narrow and finally obliterated within a year are the important findings. If increments of growth are measured accurately and the correction does not follow the predicted pattern, one may suspect that the procedure has not been adequate. It is our custom, at this time, to insert a very small square of tantalum on the diaphyseal side of the plate, both medially and laterally. These squares, when visualized in serial roentgenograms, permit an accurate evaluation of the effectiveness and symmetry of the arrest. Roentgenograms of the area should be taken every three months until the epiphysis at the site of arrest has been completely obliterated. Careful clinical examinations should be performed at regular intervals, during the same period, to record any tendency toward deformity.

The technique of the operation seems to be the largest factor in determining the effectiveness of the procedure and the incidence of deformities. Certain of the surgeons carrying out the procedure in this series have had no cases in which deformities developed, and all of their arrests have been effective immediately.

TECHNIQUE OF OPERATION

The operative technique will be discussed only in so far as it affects the results of the procedure. The technique which is recommended includes a wide, thick graft on each side —ordinarily from seven-eighths of an inch to one inch (from 2 to 2.5 centimeters) in width— which should go well beyond the epiphyseal plate into the epiphysis, yet have a much longer portion on the diaphyseal side. It should extend at least one inch into the diaphysis so that, when the graft is reversed, the cartilage in the transplanted bone is well removed from its original position. In depth at the epiphyseal plate, the graft should be at least three-quarters of an inch (2 centimeters). The exposure of the epiphysis can often be facilitated by adding a transverse cut to the longitudinal incision in the periosteum. The operative sites should be located equidistant from the anterior and posterior surfaces of the bone; this will place the grafts in exact mid-lateral and mid-medial positions. The epiphyseal plate is drilled carefully throughout its extent with a hand drill, entry being made through the site from which the graft has been removed. The first drill point used is one-eighth of an inch in diameter, so that the cartilage may be followed accurately, by palpation with the drill point, as the drilling is performed. After this, drill points three-sixteenths of an inch and one-quarter inch in diameter are used, so that the epiphyseal plate will be thoroughly obliterated. Slivers of cancellous bone, pried from the bed of the graft in its extent in the

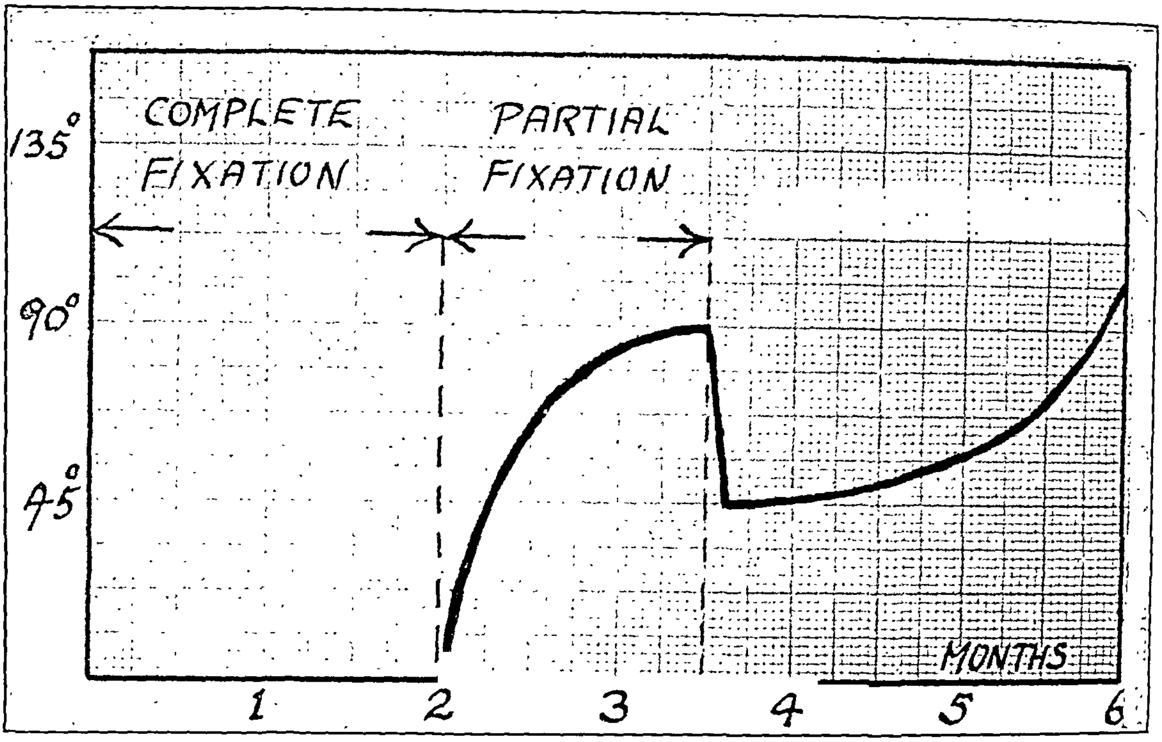

Fig. 4-A

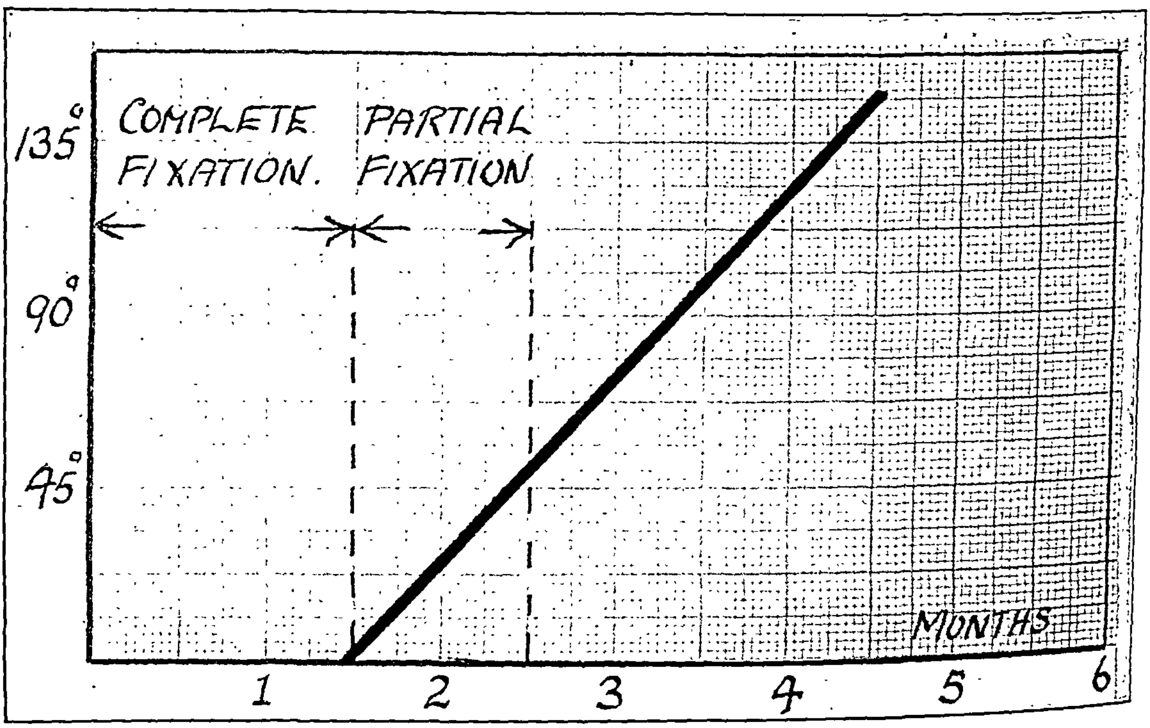

Fig. 4-B

In Fig. 4-A is seen the sudden deterioration of knee movement after the thirteenth week, when all external support had been discarded. This depressed range persisted for about one month before spontaneous recovery started. It is postulated that this spontaneous recovery was held in abeyance until true consolidation of the fracture had been assured, and that the return of knee movement was not a simple mechanical phenomenon, but was primarily dependent upon the state of the fracture.

In Fig. 4-B is *illustrated a case in which strong bony union took place without incident* and without any threat of re-fracture or late angulation. Knee movement returned spontaneously and progressively.

(average time was 6.8 weeks) had an average range of motion of 114.1 degrees, six months after fracture. Those patients who did not show clinical union until after eight weeks (average time was 15.3 weeks) had an average range of motion of 74.5 degrees six months after fracture (average difference was 39.6 degrees at six months). At one year after frac-

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DISCUSSION

DR. FREDERIC C. BOST, SAN FRANCISCO, CALIFORNIA: Since the origination of epiphyseal arrest by Dr. Phemister, other methods of equalizing leg lengths have rarely been necessary. The use of epiphyseal arrest requires exact information regarding the growth of bone. Quite accurate information concerning the growth of bone was adduced by Hatcher, by Gill and Abbott, and by J. Warren White. All of them used information obtained from records made by other observers who were concerned with the general growth of the child, and information obtained by anthropological studies. It is interesting that these methods of estimation should prove so nearly correct, as Dr. Green has pointed out in his present paper.

Dr. Green is the first to give us very accurate information concerning the growth of bone. These data he has obtained by serial roentgenograms made at half-year or yearly intervals. From the information which he obtained, he has presented a simple chart which shows the average growth to be expected at any given age. This chart is sufficiently accurate to be of practical use in treating patients who have inequality in lengths of the lower extremities.

Dr. Green's statistics are based upon measurements obtained from a large number of children, but much more information must be adduced before the measurements may be considered infallible. While exact equality of lengths is not essential for a good clinical result, nonetheless we should all collect further information concerning bone growth in order that greater accuracy may be possible. Dr. Green's measurements were made from orthoroentgenograms, a measurement which he described in an earlier paper. Scanography, described by Millwee and also by Gill, would seem to be an even more accurate method for measuring actual bone length.

DR. J. WARREN WHITE, GREENVILLE, SOUTH CAROLINA: I want to express my appreciation for these papers, which are a real help to those of us who are intensely interested in this subject. I would like to ask Dr. Green, who persuaded me eight months ago to take cognizance of bone age, about the determination of this important figure. In every roentgenogram we have taken, we have had trouble making this determination. I hope that something will be published soon which will be more accurate than the Todd method. We recently have been in communication with Dr. Bayley of the University of California, and she has sent information which has been of considerable value. I wonder if Dr. Green can give us some information by which we can more accurately interpret the bone age.

DR. W. T. GREEN, BOSTON, MASSACHUSETTS (closing): As regards Dr. Bost's comment concerning the accuracy of the roentgenographic method, I should like to say that the method is accurate, as the determination depends upon focusing the tube consecutively over each joint, and hence upon the interception of the ends of each bone by parallel rays. This avoids magnification. The point of focus is recorded on the film by a marker in every instance, thus allowing us to check the technical accuracy of each film.

We shall always have some difficulty in predicting the effect of an arrest until we understand better the patterns of skeletal maturation, and are able to judge skeletal maturity more accurately. In 88 per cent.

(*Continued on page 678*)

at six months, and the range at twelve months was 135 degrees (the patient was of spare build, and full range was estimated at 150 degrees). The final range was good, but, although motion was started earliest in this series, final range was not so complete as in a number of other cases which were treated by much slower methods.

That the recovery of the last few degrees of full flexion is not dependent upon simple mechanical factors in early treatment would seem to be fairly obvious. The recovery of full range depends upon the complete absorption of all scar tissue in the region of the healing fracture. It is difficult to see how exercise of the knee, during the first three weeks, on a limited range centered on the semi-extended position, can have much direct influence on the return of the last few degrees in the position of full flexion some nine to twelve months later (Fig. 5). The production of minimum scar tissue around a fracture is dependent upon biological factors and not upon simple mechanical movement of the knee.

FINAL KNEE RANGE IN THE PRESENT SERIES

The thirty-four cases in this series were treated with fixed traction on a straight Thomas splint in accordance with the basic principles of Thomas, and as discussed in a previous paper [2]. The prolonged fixation of the knee, according to the classical method [3], was abandoned as soon as evidence of clinical union at the fracture site had been detected.

It is of interest to note, in view of the satisfactory range of final knee motion, that the exercises * for knee flexion, when first started at about the eighth week, rarely lasted for more than five or ten minutes twice a day. This tentative knee exercise was made a sideline to quadriceps drill, in the belief that static contraction of the quadriceps could free the muscle fibers from adhesion to the fracture site. These contractions affected the whole extensor apparatus, from the muscle fibers to the lateral expansions of the joint capsule.

The results of this series are indicated in Tables II and III. The average age of the patients was 26.5 years. Clinical union of the bone was detected, and motion of the knee was started at the average time of ten and one-quarter weeks. The average range of motion of the knee after twelve months was 121 degrees. In those cases in which the range of motion was known at six months after fracture (twenty-seven cases out of the thirty-four) there were twenty-three patients (85 per cent.) who had 90 degrees or more.

EARLY KNEE MOVEMENT AND FRACTURE UNION

It is one of the claims of those who believe in starting early motion of the knee after a fracture of the femur that union of the femur is thereby stimulated. It is certainly true that early union by this method is more obvious than in methods employing splints, because the limb can be readily tested for union day by day.

In Tables II and III, showing the cases in which *late* knee movement was allowed, it would be difficult to imagine that early movement could consistently produce clinical union at a significantly earlier time.

A HYPOTHESIS OF KNEE MOVEMENT

Sufficient evidence concerning the behavior of the knee after fractures of the shaft of the femur has been advanced in the preceding paragraphs to warrant the attempt to bring them together into a tentative hypothesis.

It would appear reasonable to suggest that the ultimate range of knee motion depends upon two factors: a *mechanical* factor related to mobilization by physical processes, and a *biological* factor relating to the amount of scar tissue produced in the quadriceps.

* The method used for knee mobilization was simple in the extreme, but needed the constant vigilance of the physiotherapist in attendance. The fixed traction cords of the *Thomas splint* were untied, all slings were removed from behind the leg distal to the knee, and, with the masseuse supporting the calf, the leg was gently lowered until the foot touched the bed. This movement was repeated slowly a few times, and then the traction cords were retied and the slings reapplied. As the range of flexion increased, the foot of the Thomas splint was raised. There would have been risk of lateral angulation developing by this technique, if the masseuse had not been trained in retying the traction cords and readjusting the splint at the end of

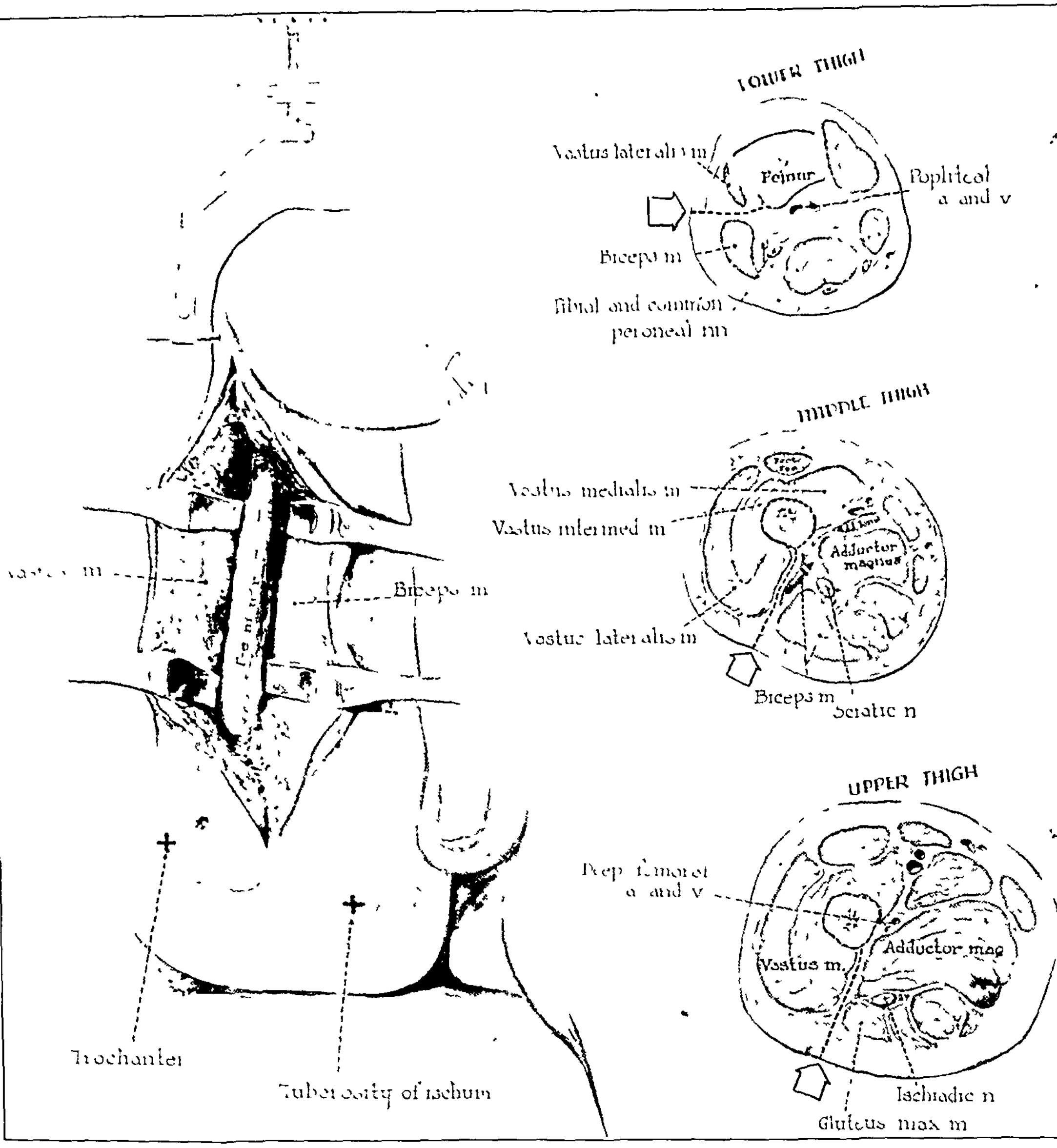

FIG. 1

surgery upon the femur, the incision may be packed open; or it may be partly or completely closed. The muscles fall together after the retractors have been removed, so that only skin closure is necessary. The fascia will repair itself.

In the experience of the Orthopaedic Service of the Twenty-third United States Army General Hospital, in treating 221 compound battle fractures of the femur[2], the incision was utilized either initially at the Forward Hospital or the Evacuation Hospital, or during reparative surgery in ninety-three cases. It was found that the approach gave easy access to the entire shaft of the femur. In several cases, the wound was so extensive, from the gluteal fold to the femoral condyle, that the entire shaft was exposed at once. Profuse bleeding, which is prevalent with the anterolateral incision, was never encountered, as only minimum division of muscles was necessary. The first, second, and third perforating branches of the profunda femoris artery were easily clamped and tied as they passed from the short head of the biceps femoris to the vastus lateralis.

When internal fixation was done, reduction and alignment were facilitated by the presence of the linea aspera and the flat surface of the femur, so that one plate with a transfixion screw, as recommended by Murray, or two plates at right angles, could be used. Adequate posterior dependent drainage of the fracture site was usually established, except

The biological factor governs the complete removal of the temporary tissues of repair. In some cases the temporary tissues of repair are converted into permanent fibrous scar tissue. Such a process causes tethering of the surrounding muscles. This almost invariably follows when there has been sepsis; but the healing of a closed fracture should leave no permanent scar tissue.

It has been the writer's constant observation that, when the femur reveals a noticeable absence of bony callus in the roentgenogram at about six weeks, there will always be a threat of limited knee motion, *even if the femur is being treated on an apparatus permitting knee exercise.* This observation is interpreted as indicating that the provisional callus, failing to become bony callus, is attempting to effect a union of the femur by permanent scar tissue and, in so doing, involves the adjacent muscles in the adhesive process. The production of large amounts of permanent scar tissue around closed fractures will only be explained when the intimate nature of delayed union is understood.

By contrast, it has been the constant observation of the writer that femora which show bony callus at from three to four weeks will unite early, and that eventually there will be perfect motion of the knee. Profuse bony callus appears to result in much less adhesion of the quadriceps than the radiotranslucent scar tissue, which presumably is present when bony callus is deficient.

When fibrous tissue is produced in the tissues surrounding a closed fracture, it is possible that the liberation of muscle fibers by mechanical movement is a futile hope. There is some collateral evidence to suggest that passive motion in these conditions may even be harmful. When myositis ossificans develops near a fracture site, it is well known that the best chance of securing a useful range of motion in the associated joint is by limitation of exercise. Passive movement in these cases can increase the area of the pathological process in the muscle fibers.

CONCLUSIONS

1. Evidence has been produced to show that adhesions in the quadriceps may be the primary cause of knee stiffness after fractures of the shaft of the femur.
2. The recovery of perfect knee movement after a fracture of the shaft of the femur depends upon the complete absorption of scar tissue involving muscle at the fracture site.
3. The production of scar tissue around a fracture and the involvement of the surrounding muscles is a biological process, related to the healing power of the fracture and unrelated to early mechanical knee motion.
4. If the fracture of the femur shows clinical union in eight weeks, final knee motion will be excellent even if the knee remains fixed throughout treatment. Scar tissue in these cases is minimum, and bony callus is plentiful.
5. If the fracture of the femur shows delayed union, it is doubtful whether mechanical knee movement will prevent considerable permanent knee stiffness. In these cases, bony callus is scanty, permanent scar tissue is plentiful, and quadriceps tethering occurs.

NOTE: The author takes pleasure in acknowledging his indebtedness to Professor Harry Platt for his constant encouragement and advice, particularly during the writing of this paper. He is also indebted to Professor S. L. Baker, Department of Pathology, University of Manchester, with whom discussions of the utmost value on the healing of fractures have been held.

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KNEE MOVEMENT FOLLOWING FRACTURES OF THE FEMORAL SHAFT *

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In this paper an attempt has been made, by clinical inference, to examine the subject of knee stiffness following a fracture of the shaft of the femur.

In the past, it has been customary to regard the maintenance of knee movement after a fracture of the femur as a simple mechanical problem. Evidence suggests, however, that knee motion after such a fracture depends only in part upon simple mechanical factors; and that the key to *perfect* joint function will be found only when the key to *early* bony union has been discovered.

A mechanical barrier to knee motion following a fracture of the shaft of the femur can involve three structures,—the articular surfaces of the joint, the capsule of the joint, and the extensor apparatus of the thigh (Fig. 1). In a severe case of long duration, probably all three sites may be involved simultaneously.

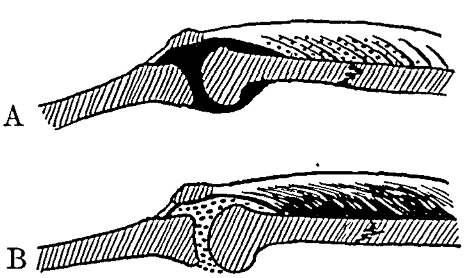

FIG. 1

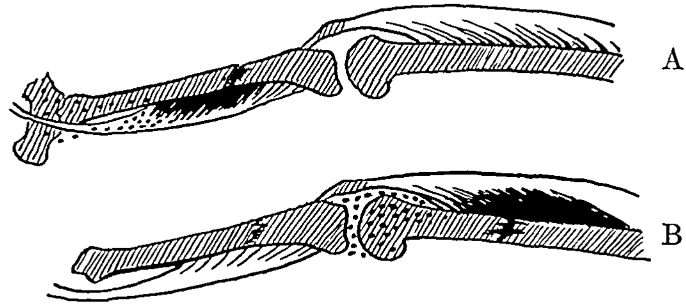

FIG. 2

Fig. 1: Showing mechanical barriers to knee motion.

A: Illustrates the orthodox conception of the usual cause of intractable knee stiffness after a fracture of the femur. Extra-articular adhesions are known to exist, but are regarded as of secondary importance.

B: Illustrates the author's conception that the "master adhesions" lie in the quadriceps and that the intra-articular adhesions are secondary, both in development and in importance.

Fig. 2: Illustrating the difference in knee stiffness after fractures of the fibula and tibia in comparison with fractures of the femur.

A: After six months' fixation for a fractured tibia, no stiffness of the knee results.

B: After fracture of the femur, the knee may be very slow to recover movement, if it has been fixed in plaster for three or four months. This is not so much the effect of the fixation on the knee as the result of fibrosis in the quadriceps which, in turn, is dependent upon the biological conditions for bony union of the fracture.

EVIDENCE FOR EXTRA-ARTICULAR ADHESIONS

The following evidence is given in favor of the theory that limitation of knee motion following a fracture of the femur is caused by extra-articular forces.

1. Comparison with Fractures of the Tibia and of the Fibula

In the treatment of fractures of the tibia and the fibula, it is not uncommon to fix the knee in plaster for six months or more, and yet little or no difficulty is experienced in achieving 90 degrees of motion at the end of a few weeks, and even full range is often secured within the same length of time.

It is possible to explain this difference in behavior in the knee joint, because in the case of the femur there might be involvement of the quadriceps femoris in scar tissue, whereas in a fracture of the tibia the quadriceps femoris is not involved (Fig. 2).

2. Injuries of the Knee Joint Unaccompanied by Fracture of the Femur

When immobilization in plaster is used for three or four months, the recovery of knee mobility after severe injuries to the ligaments of the knee is often astonishing. Sir Robert Jones has commented upon the good knee motion which is usually attained in cases of

* Based on a Hunterian Lecture delivered at the Royal College of Surgeons, May 23, 1946.

One of these difficulties is presented by removal of cartilage from the head of the femur and from the acetabulum to obtain contact of bone with bone. This reduces the size of the femoral head and increases the size of the acetabulum, often producing gross disproportion, which contributes to instability and rotary movement of the joint, and prevents its satisfactory fusion. When internal fixation is applied, however, without any intra-articular procedure, the joint may be fixed in malposition, perpetuating the deformity and requiring additional surgical treatment.

The authors have been attempting constantly to devise a procedure which would take account of the foregoing difficulties, and would fulfill other desiderata in connection with the relief of pain in the hip by arthrodesis. The following factors were considered important: (1) The operation should be performed in one stage, in order to reduce the surgical hazards and the expense to the patient. (2) The adduction and flexion deformities should be corrected before application of internal fixation. This should be done, if possible, without dislocation of the hip, in order to minimize shock. (3) The cartilage on the head of the femur and that lining the acetabulum should not be removed and discarded, since this leads to instability of the joint and delay in bridging of bone across the joint, despite the bone contact so produced. (4) Internal fixation with a nail should be used to avoid immobilization in plaster, and to lessen the risk of complications and the length of time spent in the hospital. (5) A graft should be used to increase stability and ensure fusion of the joint.

The following technique has been developed to satisfy these conditions. It combines the advantages and avoids the disadvantages of other procedures, and is productive of excellent clinical results.

TECHNIQUE

The hip joint is exposed by a Smith-Petersen incision. In the first operations performed with this technique, the distal end of the incision was extended laterally to allow exposure of the subtrochanteric region. This required considerable dissection of tissues, so that, in later cases, it has been found preferable to make a second small lateral incision for insertion of the nail.

With the special curved chisel devised for arthroplasty by Smith-Petersen, the fibrous union between the femoral head and the acetabulum is broken up and the cartilage on both surfaces of the joint is thoroughly laminated. This allows correction of adduction and flexion deformities, and roughens the cartilaginous surfaces. If the joint has been sufficiently freed by this method, it is possible to manipulate it without dislocation of the femoral head, so as to achieve the ideal position, which is flexion of 30 degrees, abduction of not more than 5 to 10 degrees, and slight external rotation (about 5 to 10 degrees).

The secondary incision is then made; and the femur is nailed to the ilium by means of a Vitallium or steel nail, about five and one-half or six inches long, under roentgenographic control. The nail is driven through the neck and head of the femur and deep into the expanded thick area of the ilium, over the superior roof of the acetabulum. As other authors [9] have noted, one may encounter difficulty in driving the nail into the sclerosed bone in the acetabulum. The procedure is facilitated if that portion of the bone is well laminated with the chisel at the time the femoral head is being freed from the acetabulum. The fact that the nail is hard to drive into the acetabulum makes the head and neck of the femur ride down on the nail during its insertion, so that special care should be taken to see that thorough impaction of the joint has been accomplished, before the nail is finally driven in. It has been found advantageous to tap the impactor and the nail alternately until the nail is finally placed.

A block of bone is removed from the anterolateral surface of the femoral neck and head and from the acetabular margin, forming a slot, into which a graft taken from the ilium is fitted like a key. The graft is then thoroughly impacted in its bed, and the proce-

TABLE I

RANGE OF KNEE MOVEMENT AT SIX AND AT TWELVE MONTHS AFTER FRACTURE OF THE FEMUR IN RELATION TO CLINICAL UNION

	Time of Union (*Weeks*)	Knee Range at Six Months (*Degrees*)	Knee Range at Twelve Months (*Degrees*)
Before Eight Weeks			
	6	145	150
	8	90	120
	6	90	120
	6	120	150
	8	...	100
	6	120	...
	6	120	150
	6	150	150
	6	120	135
	3	90	135
	6	120	...
	8*	...	135
	7*	110	120
	8*	110	120
	6*	120	140
	8*	..	120
	8*	90	120
	8*	..	120
	8*	110	120
	8*	120	120
Averages	6.8	114.1	129.1
After Eight Weeks			
	14	30	90
	16	90	120
	12	90	135
	32	...	120
	10	90	90
	20	...	80
	24	...	120
	12	..	150
	10*	120	135
	10*	90	90
	13*	45	110
	9*	120	135
	16*	50	100
	16*	20	...
Averages	15.3	74.5	113.5

* Denotes fractures which are open, but without bone sepsis after one month.

UNION AND RANGE OF MOTION

Of all the factors influencing the final range of motion of the knee after a fracture of the femur, speed of union is probably the most important. If union occurs quickly, the ultimate range of motion will be excellent, even if it has been necessary to keep the knee fixed throughout treatment.

The figures in Table I were obtained from a series of thirty-four fractures of the shaft of the femur. All of the patients selected were free from sepsis after four weeks, and were in the age group of twenty to forty-five years. Knee movement was not begun until clinical union could be detected. Those patients who showed clinical union at or before eight weeks

dure is completed by thoroughly impacting the hip joint again to assure a dovetailing of the laminated cartilage. If this is accomplished, much delay in procuring firm bony union can be avoided; and the patient will experience very little, if any, discomfort in the hip joint after operation.

Shock during the operation is greatly minimized by the fact that the hip has not been dislocated. Transfusions of whole blood are used, as indicated. No plaster cast is applied, and the patient is allowed to turn freely in bed during the entire postoperative period. The head of the bed can be raised slightly, since there is fixed flexion of the hip of 30 degrees, but undue strain should be avoided until healing has been well established. Since a cast is not used, early motion of the knee is facilitated; and the development of stiffness in that joint is prevented. The patient can be placed face downward in bed, and motion of the knee joint can be started very soon after the operation. Usually the authors' patients have been up on crutches in from four to six weeks; it is believed that perhaps this period of confinement to bed could be reduced still further, without risk of interference with fusion of the joint. The amount of activity permitted, however, must be governed by a proper respect for the underlying principles of bone healing, which means that undue stress and strain should not be applied until sufficient healing has been accomplished to ensure union. If this precept is followed, there will be no tendency toward recurrence of the deformity; and the best functional result will be assured.

RESULTS

During the past few years, this procedure has been carried out on ten patients with painful hips; in most of them, the disability was caused by chronic hypertrophic arthritis.

FIG. 3-A FIG. 3-B

Fig. 3-A: Case 6. Roentgenogram showing old fracture of the neck of the left femur, with pronounced aseptic necrosis of the femoral head.

Fig. 3-B: Solid fusion of the hip joint is seen, twenty months after operation.

ture, the average ranges were respectively 129.1 degrees and 113.5 degrees (average difference was 15.6 degrees at twelve months).

RANGE OF MOTION AND SOUNDNESS OF UNION

The existence of some relationship between sound union and recovery of knee motion is illustrated by the following experience.

It often happens that a patient with a fractured femur, who has been allowed early movement, may have attained a considerable range of motion in the knee by the end of three months, and by this time union may appear to be clinically firm. If the limb is then taken off traction and allowed to lie free in bed, it may happen that after a few days the range of motion will diminish very noticeably. This may occur in spite of the fact that repeated clinical tests have failed to reveal any of the ordinary signs of threatened angulation or re-fracture (such as the reappearance of tenderness over the callus or actual movement at the site of the fracture). This temporary loss of motion may persist for some weeks before the range of motion eventually equals, and later exceeds, that secured while the limb was in traction.

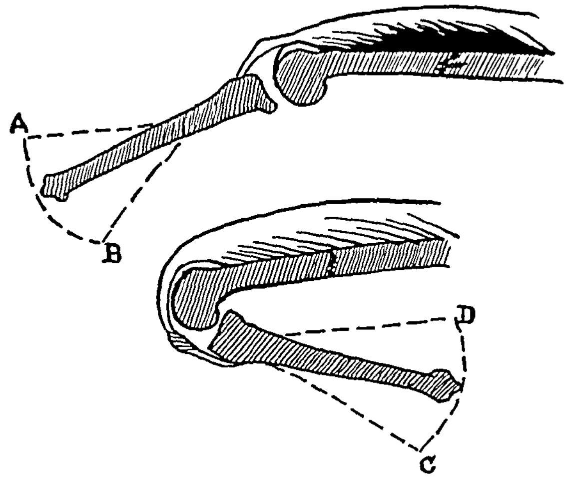

Fig. 5

Mechanical exercise over the arc *BA* at or before six weeks can have no direct influence on the final recovery of the range in the arc *DC* some six months later. Recovery of the range *DC* is dependent upon biological factors at the fracture site, which determine whether the provisional callus is absorbed completely or leaves permanent scar tissue in the muscle.

An example of such a result is demonstrated in Figure 4-A. The figures here were taken from an actual case. Knee movement was started at the end of the seventh week after fracture, the bone by that time being clinically solid at the fracture site. The range of motion of the knee increased rapidly at first until 90 degrees was reached. At this point, clinical union still seemed sound; indeed the patient regarded his splints as futile, and waved them around the bed by active contractions of the quadriceps. Splintage was removed; the next day the range of motion had fallen to 45 degrees. This lowered range persisted for about four weeks, although the limb was free to be exercised at all hours of the day, instead of at limited and prescribed periods under supervision, as had been the regimen before the splint was removed. After the range of motion had started to improve, 120 degrees was attained in six months.

It is this type of case which makes the critical observer wonder whether, in an exactly controlled series, any outstanding difference in the *ultimate* range of the knee would be revealed as the result of different forms of treatment. The common "hold-up", which is so often encountered at about the 90-degree range, tends to eliminate the difference in final results between cases in which motion was started early and those in which it was started late.*

RECOVERY OF COMPLETE RANGE IN FLEXION

The longer the knee joint is immobilized, the greater will be the permanent stiffness. On the other hand, very early movement does not guarantee full recovery of knee range.

In one case of a mid-shaft fracture of the femur, the knee was started on assisted movement at three weeks, in an experimental device permitting a free range of 90 degrees while on traction (a device which proved too elaborate for general routine use). The patient secured 90 degrees of motion at seven weeks. At the end of twelve weeks, his fracture had united, and the splints were abandoned. He secured no more than 90 degrees

* In judging this statement, the clinician must guard against an erroneous general impression from the results of early and late knee movement in an uncontrolled series. Only too often those cases which respond well to early knee movement are taken as examples of that method, and *those cases in which early movement has had to be abandoned for various complications are relegated to the class of late knee movement.*

TABLE I

CLINICAL RESULTS FOLLOWING MODIFIED ONE-STAGE PROCEDURE FOR ARTHODESIS OF THE HIP JOINT

Case No.	Sex	Age	Condition Before Operation	Date of Operation	Clinical Results *
1	M.	50	Traumatic arthritis. For several years unable to walk without crutches, because of pain. Using a graft and cast, the authors had made two unsuccessful attempts to fuse the left hip joint.	Feb. 1, 1938	Complete relief of pain. Excellent fusion had occurred four months after operation.
2	F.	62	Hypertrophic arthritis. Severe pain on attempted motion. Flexion deformity of 45 degrees in left hip.	Oct. 9, 1941	Was walking on crutches eight weeks after operation, without pain. Hip joint fused in good position. Two years later, patient reported she was walking well and had no pain.
3	F.	38	Hypertrophic arthritis of right hip. Adduction of 15 degrees; flexion of 80 degrees.	Sept. 4, 1942	Was walking with crutches, without pain, eight weeks after operation. Hip deformity corrected. Four years later, patient stated that she could walk as far as she desired, and had no difficulty in sitting. Hip fused.
4	M.	64	Hypertrophic arthritis. Pain of increasing severity. Only a few degrees of motion in right hip. Joint position satisfactory.	Apr. 13, 1943	Patient walked with crutches, four weeks after operation. Hip joint solidly fused at ten weeks. Two years after operation, was walking well, with no pain.
5	M.	55	Hypertrophic arthritis of right hip. Flexion of 35 degrees; adduction of 20 degrees.	Aug. 24, 1943	Was walking with crutches in four weeks. Hip was solidly fused in good position at four and one-half months. Patient was walking well, with no pain, when seen eleven months after operation.

TABLE II

KNEE RANGE IN NINETEEN CASES OF CLOSED FRACTURE

Patient	Age (*Years*)	Time in Fixation (*Weeks*)	Degrees of Knee Range		
			After 6 Months	After 12 Months	After 24 Months
C.	28	6	145	150	150
C.	26	8+6	30	90	...
C.	26	16	90	120	...
C.	28	7	120	...	...
D.	28	8	90	120	135
R. G.	28	6	90	...	120
L. G.	28	8+4	90	...	135
H.	24	6	120	150	150
J.	28	32	...	120	...
L.	20	10	90	90	120
M.	33	14+6	...	80	...
McL.	24	8	...	100	100
P.	41	6	120	...	...
R. S.	19	6	150	150	150
L. S.	19	6	150	150	150
S.	24	6	120	135	...
G. S.	20	3	90	...	135
U.	41	24	...	120	120
W.	37	8+4	120	150	150
Averages	27.5	11	108	123	135

TABLE III

KNEE RANGE IN FIFTEEN CASES OF COMPOUND FRACTURE WITHOUT SEPSIS

Patient	Age (*Years*)	Time in Fixation (*Weeks*)	Degrees of Knee Range		
			After 6 Months	After 12 Months	After 24 Months
B.	22	8	...	...	135
C.	34	7	110	120	...
C.	26	8	110	120	135
C.	21	6	120	140	140
D.	28	10	120	135	135
D.	23	10	90	90	90
H.	23	8	...	...	120
K.	28	8	90	...	120
P.	29	13	45	110	120
P.	20	5+4	120	135	...
R.	25	8	...	120	150
S.	32	16	50	100	100
S.	24	8	110	120	135
S.	22	16	20	...	100
T.	25	8	120	120	135
Averages	25.5	9.5	92	119	124

The mechanical factor is obvious. It is the freeing of muscle from involvement in callus by simple mechanical movement. Some other factor must be present in addition to the simple mechanical factor, however, because early knee motion does not always result in a perfect knee, and, on the other hand, late knee motion can often produce a mobile knee.

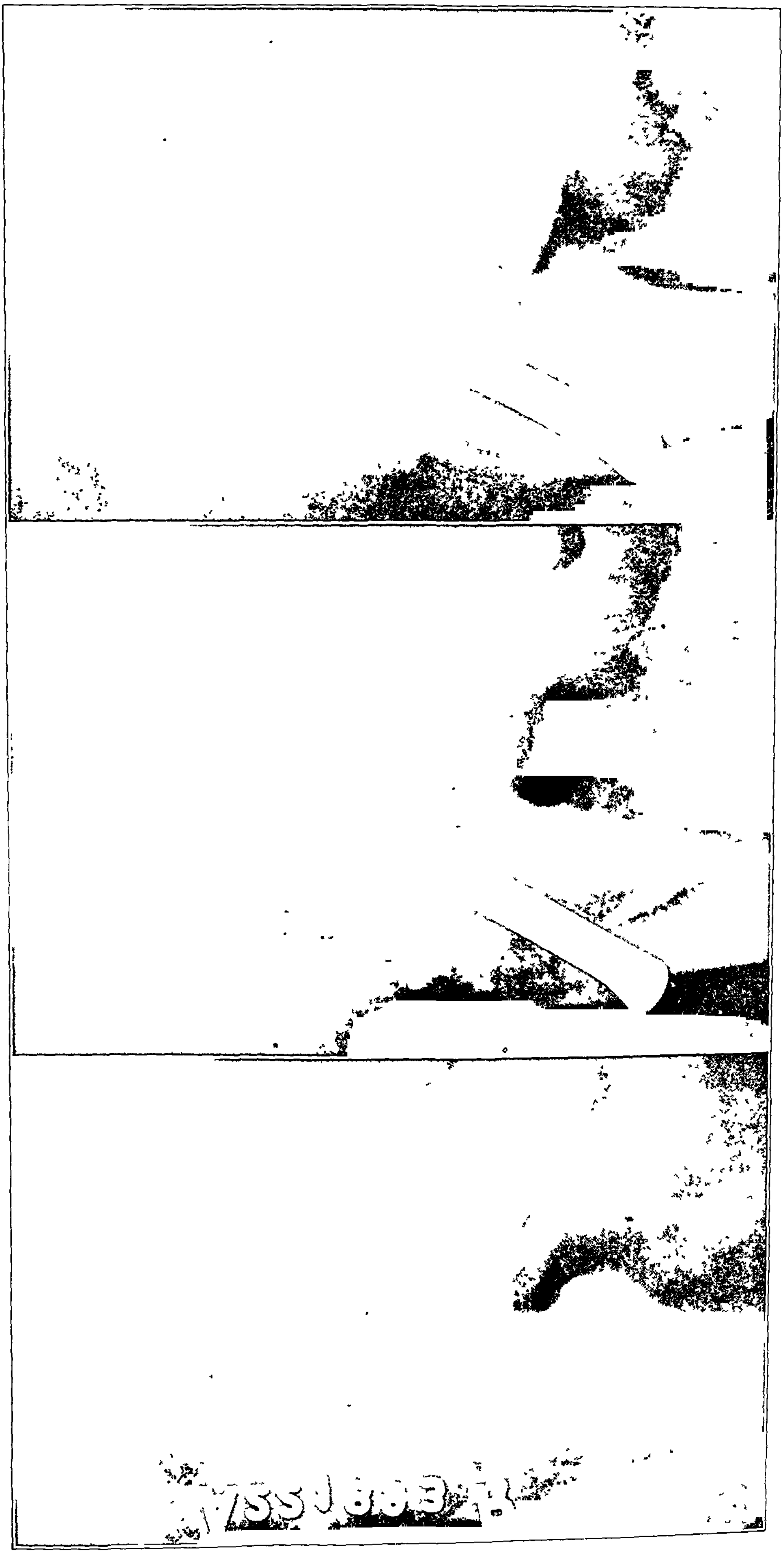

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: Case 9. Roentgenogram, taken before operation, shows hypertrophic arthritis of the right hip joint.
Fig. 5-B: Roentgenogram, two months after operation, shows graft and nail in position.
Fig. 5-C: Showing solid fusion of the right hip joint, eight months after operation.

ARTHRODESIS OF THE HIP JOINT IN DEGENERATIVE ARTHRITIS

A Modified One-Stage Procedure with Internal Fixation

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The general consensus [3,4,6,8] among orthopaedic surgeons who have experimented with various surgical procedures for the relief of painful hip joints in degenerative arthritis is that arthrodesis is the most satisfactory method; but the operation has presented certain difficulties and hazards that have tended to limit its application in practice. During the past decade, there has been increasing interest in the surgical treatment of the hip, stimulated in large part by Smith-Petersen's work on acetabuloplasty and arthroplasty. This has furnished a valuable contribution in this field, and has yielded more flexibility in choice of procedures for surgical treatment; but it has also led to the realization that mobility of the joint does not always solve the problem or afford the patient the desired relief. When there is bilateral hip involvement, and in numerous other cases, maintenance or increase of motion may be desirable; but there remains a certain group of cases, particularly those with one painful hip resulting from degenerative arthritis, in which relief of pain is the prime or sole purpose of treatment, and this desired result can be achieved only by fixation of the hip joint in the best possible position for function. The technique described here has been developed especially for the management of such cases.

In addition to the fact that successful arthrodesis has not been obtained in all cases in which it has been attempted by other procedures, the main disadvantages of these operations have been: (1) The procedures have been formidable and time-consuming, often productive of severe surgical shock; (2) they have required long periods of immobilization in plaster casts, presenting the serious hazard of postoperative complications in the elderly patient; and (3) they have involved great financial expense.

Older methods [1,2] of hip fusion usually consisted in removal of cartilage and fibrous tissue from the joint; they required disarticulation, with insertion of some type of intra-articular or extra-articular graft, followed by external fixation in a plaster spica until fusion had been secured. When the joint cartilage was not removed, the hip was fused with a graft; and any deformity present was retained or had to be corrected by a secondary osteotomy. Although some orthopaedic surgeons [4,8] still use these methods, there has been increasing interest in the application of the principle of internal fixation, first made popular by Watson-Jones. He contended that the clue to successful fusion, after the joint has been denuded of cartilage, is control of rotary movement, a control which cannot be assured by the plaster spica, but which can be assured by a three-flanged nail driven from the femur into the pelvis. In addition, he applied a plaster spica, and kept the patient immobilized for three months. At first he performed the operation in one stage, but this proved too formidable, especially in elderly patients, so it was later done in two stages, with insertion of the nail and application of plaster ten to fourteen days after the intra-articular procedure.

The Watson-Jones operation has been advocated as the procedure of choice by Campbell and Haggart. Numerous modifications of this technique, using internal fixation with a metal nail, with or without additional bone grafts, and with or without disarticulation and removal of cartilage from the joint, have been advanced during the past few years by White, Harris, and Niebauer and King. In the authors' opinion, all of these different methods have certain advantages and disadvantages, but none quite overcomes the salient difficulties.

joints are kept mobile, there has been no increased stiffness in the knees or other joints during the period of fusion of the hip joint.

Although the present series of cases is not large, fusion has been achieved by this simplified technique of arthrodesis in a higher proportion of instances than has been reported by other authors, using other surgical methods. With earlier techniques and the use of external fixation, failure or incomplete fusion occurred in as many as 50 per cent. of the cases in some series. The results achieved with various techniques employing internal fixation[7,9,13] have been more satisfactory in this respect, but have included some failures to achieve bony union. Furthermore, these other methods present greater surgical risk, are more difficult to perform, usually require two operations, and keep the patient incapacitated for a much longer period.

The simplified one-stage procedure described here seems to recommend itself on the basis that it embodies the best principles of the surgical techniques described previously. In addition, it overcomes their main difficulties, corrects deformities, provides the best possible chance for joint fusion, avoids the hazards presented by plaster immobilization, and greatly reduces the length of time spent in the hospital.

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FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 2. Roentgenogram taken before operation shows pronounced arthritis of the left hip.
Fig. 1-B: Shows solid fusion of the left hip joint, five months after operation.

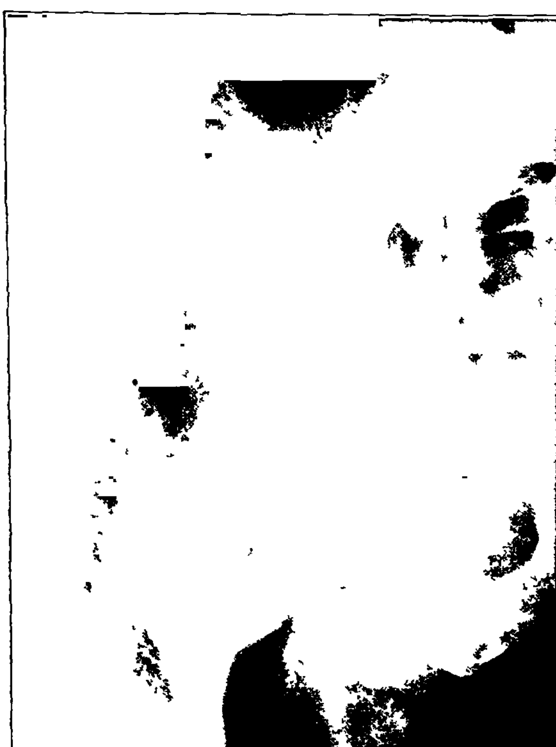

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 4. Roentgenogram shows extensive hypertrophic arthritis of the right hip joint.
Fig. 2-B: Shows solid fusion of the right hip joint, three years after operation.

CLINICAL FEATURES

History: The usual presenting symptom of a patient with osteochondritis dissecans of the talus is pain and tenderness at the site of the lesion. In some cases, swelling and intra-articular effusion are present. Pain and swelling subside with rest and elevation of the leg; however, tenderness usually persists for an indefinite length of time. The majority of patients give a history of trauma. In some cases the injury is relatively mild; some patients give a history of repeated minor traumata; and in a few cases there is a history of direct trauma across the dorsum of the foot and ankle. Patients usually present themselves for examination because of chronic ankle pain or fatigue; and in some instances the lesion is found during roentgenographic examination for an acute sprain of the ankle.

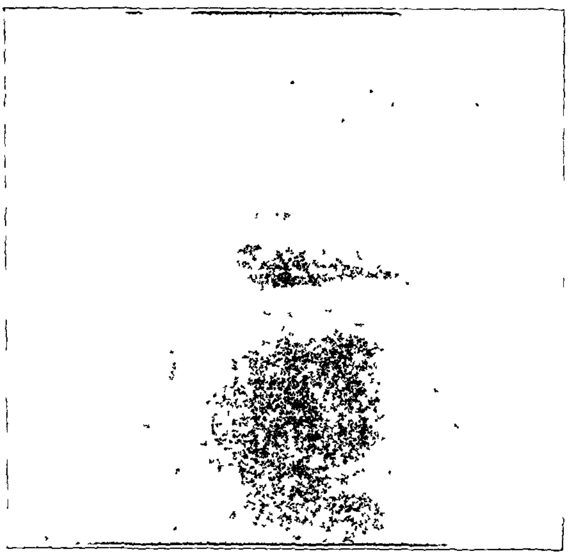

FIG. 1

Case 1. Anteroposterior roentgenogram shows a moderately advanced lesion of osteochondritis dissecans, involving the superomedial articular surface of the talus.

Physical Examination: Physical examination may or may not disclose swelling, depending upon the stage of the lesion. In early cases, swelling is absent. In the long-standing case, however, chronic oedema and periarticular thickening may be present. There is usually local tenderness, at times exquisite, at the site of the lesion. There are no signs of inflammation. *Limitation of motion,* locking, instability, giving way, or palpation of a loose body is dependent upon the stage of the lesion, and may be present in the advanced case. Joint motion is usually within normal limits, and physical examination in early cases may be remarkable chiefly because of its negative findings.

LABORATORY DATA

In this series of cases, blood studies, including the sedimentation rate, calcium and phosphorus determinations, serological tests for syphilis, and the usual determinations of red cells, white cells, and hemoglobin, were all within normal limits. Urinalyses, including tests for Bence-Jones bodies, were negative. Cultures taken from the site of the lesion at the time of operation were all negative, when grown both aerobically and anaerobically.

ROENTGENOGRAMS

Although roentgenographic examination is the principal method of diagnosis, routine anteroposterior and lateral views often fail to demonstrate the lesion. This failure is probably due to the fact that the superolateral or medial pole of the talus, which is the usual site of the lesion, may be hidden by the superimposed lateral or medial malleolus. However, careful oblique projections will demonstrate the lesion (Figs. 2-A, 2-B, and 2-C, and 4-A to 4-E, inclusive).

In eleven of the fourteen cases studied by the authors, the lesion was located on the medial border of the superior articular surface of the talus, while in the remaining three it was located on the superolateral articular surface. Mensor and Melody described the use of tomography in making the diagnosis. However, this method entails the use of special equipment; and the authors feel that careful anteroposterior, lateral, and oblique roentgenograms are sufficiently accurate to suggest the diagnosis without the necessity for special equipment.

The clinical data in these cases are summarized in Table I. All but three of the patients were fifty years old or over; five were men and five were women. There have been no postoperative complications, and complete fusion of the joint has occurred in all cases (Figs. 1-B, 2-B, 3-B, 4-B, 5-C, and 6-D). In one instance (Case 1) the authors had made two unsuccessful attempts at fusion of the joint by insertion of a graft and external fixation in plaster, a year and two years previously. Adduction and excessive flexion deformities, present before operation, have been overcome (Figs. 6-A and 6-B) in all but one instance, in which slight adduction persists (Case 6). This apparently was due to insufficient correction at the time of operation.

DISCUSSION

Some authors[4] have emphasized that it is at times difficult to persuade patients to submit to arthrodesis of the hip, since they object to having a permanently stiff joint. The authors have not encountered such objections in their patients. In most cases, the joint is almost completely ankylosed anyway; but the patients have pain because some movement is retained and because the joint is fixed in a bad position. We find that they are so anxious to have their pain relieved that they are not unduly concerned about acquiring a stiff joint in the process. The point has also been made that, if there is pain or other evidence of arthritic involvement in the spine, the hip fusion will not be successful in relieving the pain. In several of the authors' patients, correction of the flexion-adduction deformity of the hip joint apparently contributed also to relief of pain in the back, which had been present before operation.

With the technique described, no serious surgical shock has been observed. The patients have been comfortable after operation, and no complications have developed. Since movement in bed is possible throughout the postoperative period, and the knee

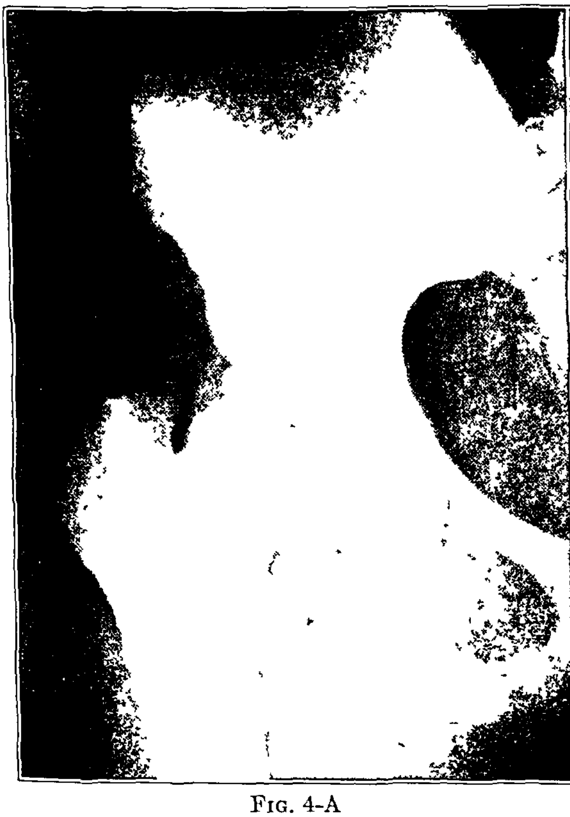

Fig. 4-A

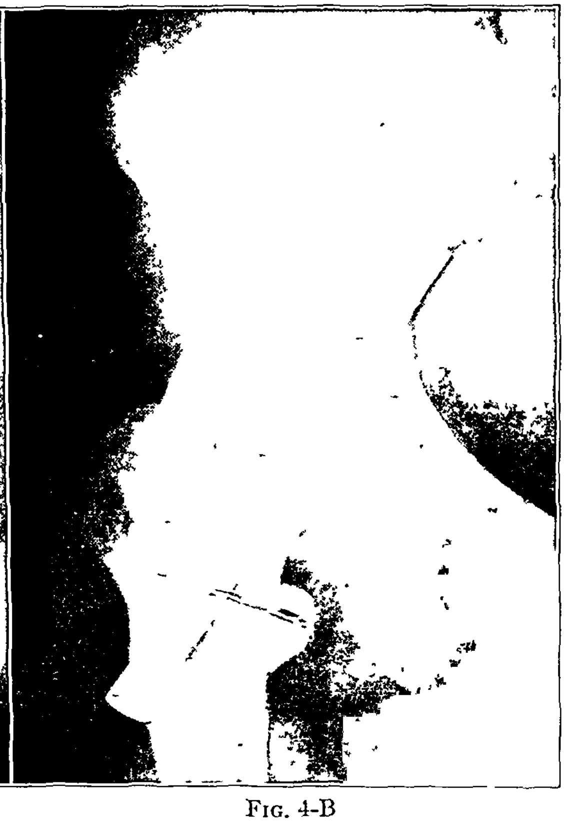

Fig. 4-B

Fig. 4-A: Case 7. Roentgenogram shows low-grade infectious arthritis of the right hip.
Fig. 4-B: Shows solid fusion of the hip joint, thirteen months after operation.

and, in ~~advanced~~ cases, is necrotic. Morton and Crysler, in discussing osteochondrit dissecans of the supratrochlear septum, considered the microscopic pathological appea ance to be that of necrosis with foreign-body giant cells and low-grade aseptic inflamma tion. The authors have found no evidence of inflammation in any of their cases.

TREATMENT

In the early cases, in which the lesion is discovered accidentally and no definit symptoms are referable to the site of the lesion, operative intervention should be delaye until symptoms develop, or until roentgenograms demonstrate unquestionable progres sion of the lesion. When the diagnosis has been established and the patient is havin symptoms referable to the site of the lesion, surgical intervention is the only satisfactor method of treatment. Cases of spontaneous healing of the lesions of osteochondritis dis secans have been reported, but the authors agree with Cohen that they probably repre sent healing of an osteochondral fracture rather than true osteochondritis dissecans.

OPERATIVE TECHNIQUE

Surgical Approach: The particular surgical approach to be used is necessarily deter mined by the location of the lesion. If the lesion is on the superomedial aspect of the talus, an anteromedial incision may suffice. However, in some cases the lesion may be hidden completely by the medial malleolus; and exposure of the site of the lesion may be extremely difficult, if not impossible, through an anteromedial incision. In this type of case the authors have employed a modification of the approach first described by König and Schäfer. In the modification of this method, a straight anteromedial incision is made just anterior to the medial malleolus. Through this incision the joint may be opened, and an estimate of the availability of the lesion can be made. If the lesion cannot be reached through this approach, the incision is extended in a curved fashion around the tip of the malleolus; the malleolus is then exposed and an osteotomy is performed across its base, care being taken to avoid trauma to the posterior tibial tendon, vessels, and nerve. The authors have found it very convenient to first place a drill hole obliquely from the tip of the malleolus into the body of the tibia, prior to osteotomy. This method greatly facilitates the anatomical repositioning of the fragments at the completion of the procedure, when the malleolus is replaced in its normal position and held by means of a single screw. After osteotomy of the malleolus, sharp eversion of the foot brings the lesion on the superomedial aspect readily into view. The standard anterolateral approach is used for exposure of the lesion lying at the superolateral pole of the talus; or, if the site of abnormality should lie more posteriorly, as was the situation in one of the authors' cases, the posterolateral incision may be used to good advantage. Waring has experienced difficulty in the exposure of a lateral lesion through an anterolateral approach, and concurs with the authors in the opinion that the approach described by Gatellier would be useful in this type of lesion. When this approach is used, an osteotomy of the fibula is carried out approximately three inches above its distal end. The distal ligamentous attachments are preserved; but the fibula is otherwise stripped of soft-tissue attachments, including the distal portion of the tibiofibular ligament. The distal portion of the fibula is then laid back distally, thereby exposing the lateral compartment of the ankle joint in an excellent fashion. After completion of the procedure, the fibula is replaced in its normal position and is fixed to the tibia by means of a single transversely placed screw, the soft tissues being sutured in their respective layers. The authors have employed this method with success in the open reduction of comminuted fractures involving the medial malleolus, the lateral malleolus, and the posterior lip of the tibia at the ankle (the so-called "trimalleolar" fracture), but have not employed it in the exposure of osteochondritis dissecans of the talus. Should the lesion lie posteriorly, the posterior approach with tenotomy of the tendo calcaneus may be used. Because the osteoplastic and tendoplastic procedures entail more

TABLE I (*Continued*)

Case No.	Sex	Age	Condition Before Operation	Date of Operation	Clinical Results *
6	F.	57	Aseptic necrosis of femoral head after fracture of neck of left femur. Flexion deformity of 40 degrees; adduction of 15 degrees. Severe pain.	July 20, 1944	Walking with crutches five weeks after operation, without pain. Hip was solidly fused when seen four months after operation, and patient had no pain. Adduction deformity of 5 degrees persisted, requiring slight lift on heel.
7	F.	25	Old infectious arthritis. Severe pain for five years, which acetabuloplasty had failed to relieve. Right hip in good functional position.	Apr. 18, 1944	Was walking on crutches six weeks after operation. When seen a year later, hip was solidly fused in good position. Patient walked well, with no pain.
8	M.	61	Hypertrophic arthritis; severe pain. Adduction deformity of 20 degrees. One inch apparent shortening of left lower extremity.	Mar. 8, 1946	Was walking on crutches, five weeks after operation. Three months afterward, the hip was solidly fused in corrected position. Apparent limb shortening overcome and patient walking well, without pain.
9	F.	54	Hypertrophic arthritis of right hip. Severe pain. Flexion of 45 degrees; adduction of 20 degrees.	Feb. 26, 1946	Was walking with crutches, five weeks after operation. Solid fusion had occurred five months after operation, and corrected position was maintained. Patient was walking well, without pain.
10	M.	37	Hypertrophic arthritis of left hip; old slipped epiphysis. Adduction deformity of 25 degrees; flexion of 25 degrees.	May 2, 1946	Walking with crutches six weeks after operation. At four months, hip was solidly fused and deformity was corrected. Patient was walking well, without pain.

*The time required for solid fusion is not known in each case, because of the variable intervals at which the patients returned for observation. The time given refers the follow-up studies only.

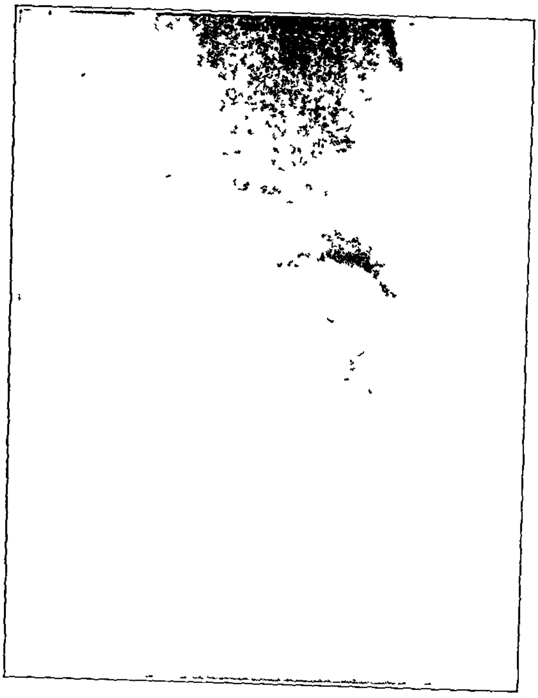

FIG. 4-A

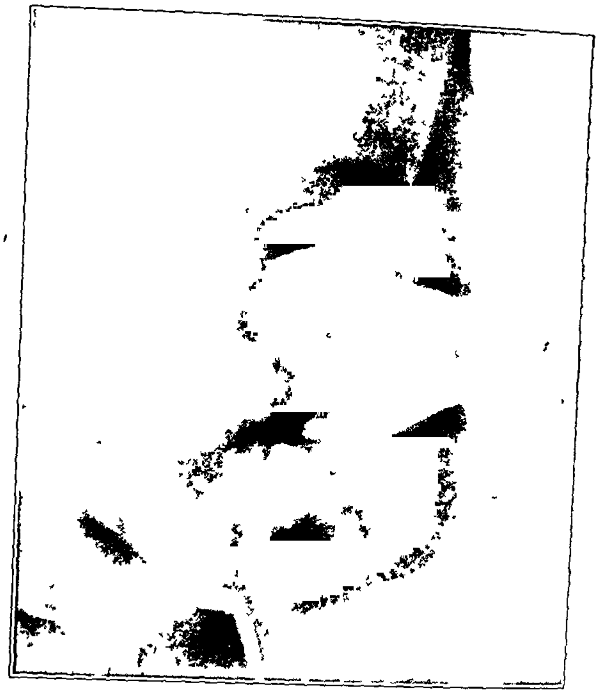

FIG. 4-B

FIG. 4-C

Fig. 4-A: Case 7. Anteroposterior roentgenogram, showing questionable lesion at the superomedial articular surface of the talus.

Fig. 4-B: In the lateral view, the lesion cannot be seen.

Fig. 4-C: The lesion of osteochondri dissecans is clearly demonstrated in t oblique view.

CASE REPORTS

CASE 3. This patient, a white ma Army mess officer, twenty-seven years ol complained of pain about the left medi malleolus, which had been present inter mittently for approximately three years The patient recalled no single incident o trauma to either ankle, and had gone through the Army Air Forces Officers Training School without much difficulty. He did, however, give a history of frequent minor or moderately severe sprains of each ankle. Physical examination was not remarkable, except for slight swelling over the anteromedial portion of the left ankle with slight tenderness over the talus, just lateral to the medial malleolus. Joint motion was normal, not crepitant, and not painful. On roentgenographic examination of the left ankle, the lesion of osteochondritis dissecans, involving the superomedial aspect of the talus, was discovered. Roentgenograms of the right ankle, taken for comparison, demonstrated an identical lesion at the same site as that present in the left ankle (Figs. 3-A and 3-B). The condition was described to this patient and operative intervention was suggested; but, since he felt that he was not having sufficient trouble with either ankle to justify an operation, he was treated conservatively with ankle strappings and physical therapy. His condition was followed for approximately six months after the diagnosis had been made; when last seen, he was continuing to have pain in the left ankle with slight swelling, but no symptoms referable to the right ankle.

CASE 6. This patient, a radio operator, thirty-four years of age, gave the history of having had his right ankle give way when he arose from a chair, twenty-two months prior to the first examination. The morning after this incident, the ankle was swollen and painful on the anteromedial aspect. Roentgenograms, taken by his local physician, were reported to reveal "a hole in the bone, but no fracture". Since the onset of the present

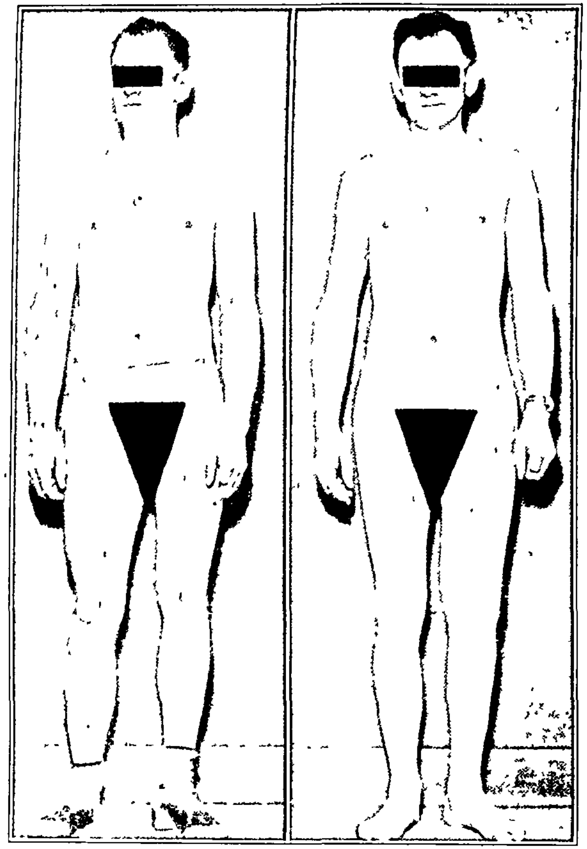

Fig. 6-A Fig. 6-B

Fig. 6-A: Case 10. Photograph taken before operation shows pelvic tilt and apparent shortening, due to the adduction and flexion deformity.

Fig. 6-B: Photograph after operation shows correction of the pelvic tilt and of the apparent shortening of the lower extremity.

Fig. 6-C Fig. 6-D

Fig. 6-C: Roentgenogram, taken before operation, shows hypertrophic arthritis of the left hip joint.
Fig. 6-D: Shows solid fusion, five months after operation.

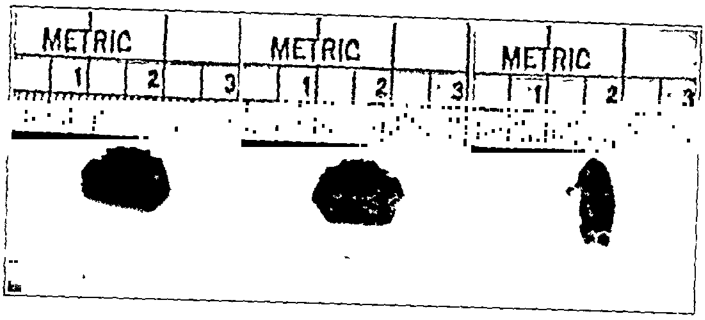

FIG. 4-F

Articular cartilage surface (left) and subchondral osseous surface (center) of osteochondral loose fragment. Edge-view of fragment, showing articular cartilage of approximately normal thickness with thin layer of detached subchondral bone, is seen at right.

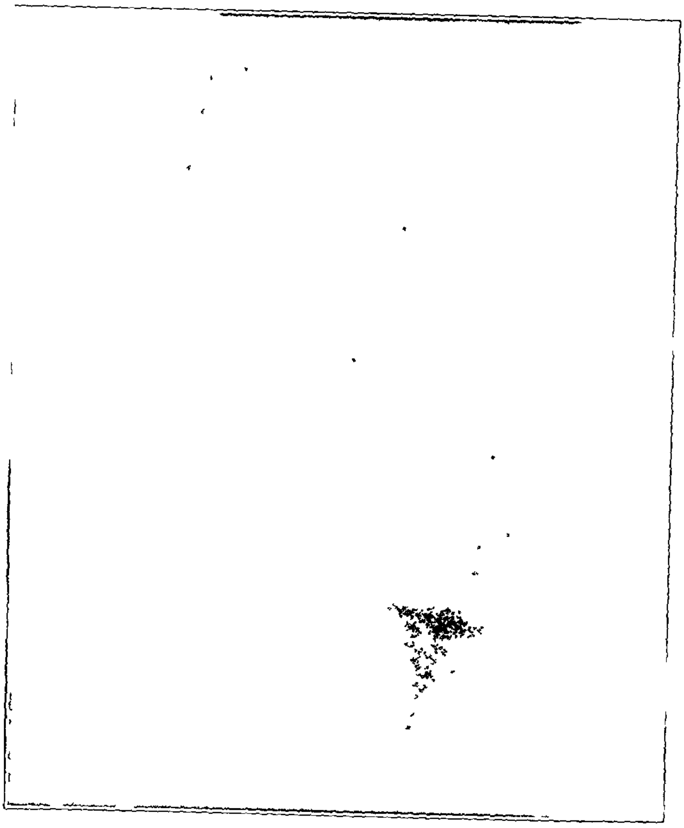

FIG. 5

Case 9. Oblique roentgenogram shows a large well-advanced lesion of osteochondritis dissecans, involving the superomedial articular surface of the talus. Note loose-body formation, cavitation, and sclerosis of bone at periphery of excavated area in talus.

osteochondral fragment was removed; and the base of the defect was saucerized. The osteotomized medial malleolus was replaced by means of a single obliquely set Vitallium screw (Figs. 4-D and 4-E). The ankle was immobilized for three weeks in a plaster-of-Paris boot cast, after which a plaster-of-Paris walking boot cast was applied. The cast was removed six weeks after operation, and the patient was allowed to walk with a adhesive strapping on his ankle. Except fo some stiffness and swelling, subsequent t immobilization, he had no pain or tender ness about the ankle, and stated that ther was no tenderness at the site of the lesion such as had existed prior to operation.

This case is too recent to permit a more adequate follow-up. Microscopic examination of the specimen removed (Fig. 4-F) showed fibrillation of the articular cartilage; the bone surface was of decreased vascularity, although not completely necrotic. The pathological diagnosis was "osteochondral articular loose body, secondary to osteochondritis dissecans of the astragalus".

CASE 9. This patient, a German prisoner of war, twenty-one years old, gave a history of having had a tree limb fall across the dorsal aspect of his left ankle while he was under shell fire, ten months before admission to the hospital. For three weel after the injury he had a painful swelling o the ankle, which gradually subsided. Follow ing subsidence of the acute traumatic reac tion, he had only occasional twinges of pain in the ankle until two months before admission, when he began to have increasing pain and swelling. Physical examination showed moderate swelling about the ankle, with fairly diffuse tenderness over the anterior portion of the ankle. Roentgenograms disclosed a large excavated defect at the superomedial pole of the talus; in this defect was a large loose body of increased density (Fig. 5).

On August 28, 1945, an arthrotomy was performed, and the loose body was readily removed through an anteromedial incision. The postoperative course was uneventful. A follow-up study of this case was impossible, because of the military circumstances involved.

SUMMARY

In this series are presented thirteen cases of osteochondritis dissecans of the talus, one of which showed bilateral symmetrical involvement of the ankle (Table I). Twelve of the patients were males and one was a female; all were white. The occupation of the individual apparently had no relation to the onset or causation of the condition.

Trauma is a major etiological factor, although in this series four patients gave no history of ankle injury. Seven of the patients had had either severe sprains or recurrent sprains of the involved ankle; two patients had had direct trauma. The duration of symptoms ranged from two months to four years, the average being 21.4 months. Since there

OSTEOCHONDRITIS DISSECANS OF THE TALUS

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The aseptic separation of a fragment of articular cartilage, with or without subchondral bone, known as osteochondritis dissecans, although more common at the knee, may involve any joint. Cases have been reported of lesions involving the shoulder, the elbow, the hip, the wrist, the metatarsophalangeal joints, and the ankle [3, 6, 8, 15, 20, 26]. Involvement of the ankle is usually in the trochlear portion of the talus, and has been considered very uncommon. Sporadic cases of osteochondritis dissecans of the talus have been reported; in 1941, Mensor and Melody reviewed the literature on the subject and reported one case, which was the twentieth case reported up to that time. Since then, four additional papers, reporting a total of nine new cases, have appeared in the literature [1, 9, 10, 19]. In addition, the authors have found a report made by Schnaberth in 1939, in which a case with extensive involvement of the talus was described. In view of the fact that, during the past four years, the authors have been able to collect a series of thirteen patients with fourteen ankles involved, and have discovered three additional cases through personal communications, it is felt worth while to report these cases and to discuss the condition in some detail.

ETIOLOGY

Although the disease now known as osteochondritis dissecans was first described by Monro in 1738, the causative factor or factors have been obscure and, in consequence thereof, the theories as to etiology are numerous. König described this condition in 1887 and stated that, without injury, fragments of various sizes become separated from the joint ends in consequence of a process as yet unexplained. In 1905 he gave the condition the name by which it is now generally known. Wagoner and Cohn, in 1931, thoroughly reviewed the theories of etiology of osteochondritis dissecans, and suggested the possibility that heredity or congenital factors were of etiological importance. Bernstein, in 1925, considered the lesions to occur in individuals congenitally predisposed to aseptic separation of an articular osteocartilaginous fragment. Conway, in his discussion of the condition in 1937, mentioned embolism of the epiphyseal arteries, a low-grade infectious process, and a congenital excessive brittleness of epiphyseal bone, leading to subchondral fracture, as possible non-traumatic etiological factors. He, however, discounted these factors in favor of trauma, even though mild, as the causative agent. Monro originally felt that the appearance of loose bodies within a joint was due to trauma; and Axhausen, in 1912, proposed the theory that, as a result of impaction from the opposing articular surface, the blood vessels to the part are damaged, either with or without partial fracture, according to the severity of the violence. This leads to necrosis of the area supplied by the damaged vessels; and as a consequence there forms a zone of absorption, resulting in gradual separation and eventual extrusion of the dead portion of the articular surface into the joint.

Fairbank believed that trauma, pure and simple, without vascular disturbance, is the sole etiological agent. Mercer supported this view, stating that, because of the rich blood supply of the subchondral bone, a vascular disturbance with aseptic sequestration of an osteochondral fragment is unlikely.

The authors are of the opinion that the condition is due to trauma—either a single recognized episode or repeated minor unnoticed traumata—with localized vascular diminution, leading to avascular separation of the loose fragment of cartilage and subchondral bone.

aspect of the talus and negative roentgenographic findings, should be followed carefully since subsequent roentgenograms may disclose the lesion.

Burr, in 1939, and Stein, Ikins, and Lowry, in 1944, stated that the "characteristic" location of the process in the talus is at the superomedial pole of the articular surface. The authors' finding of eleven lesions at the "characteristic" site and three lesions at the superolateral pole would indicate that, although found more frequently in the superomedial location, lesions do occur at the superolateral pole of the talus. Therefore, no one site should be designated as "characteristic".

Various writers, including Wagoner and Cohn, Blanco, and others, have stated that the lesions of osteochondritis dissecans are usually monarticular; and that, when more than one joint is involved, the lesions are likely to be bilateral. Case 3 in this series tends to confirm the opinions of these writers. In the case reports available, the authors have been unable to locate a previous case with bilateral involvement of the talus.

Treatment should consist of excision of the loose fragment and saucerization of the remaining defect in the articular surface of the talus. The surgical approach to the ankle joint should be considered carefully, and should be chosen only after roentgenographic study and determination of the exact location of the lesion.

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(*Continued on page 710*)

PATHOLOGICAL FINDINGS

The pathological findings in osteochondritis dissecans of the talus are similar in all respects to those found in osteochondritis dissecans of the knee or of any other joint. The gross appearance is, of course, dependent upon the stage of the lesion, and may vary from a cartilage of normal appearance with slight chondral softening and discoloration over the site of the lesion to an actual defect in the articular surface of the affected bone, with an osteocartilaginous loose body lying free within the joint. At the usual stage at which the lesion is seen, there is a yellowish discoloration of the cartilage over the site of the osteo-

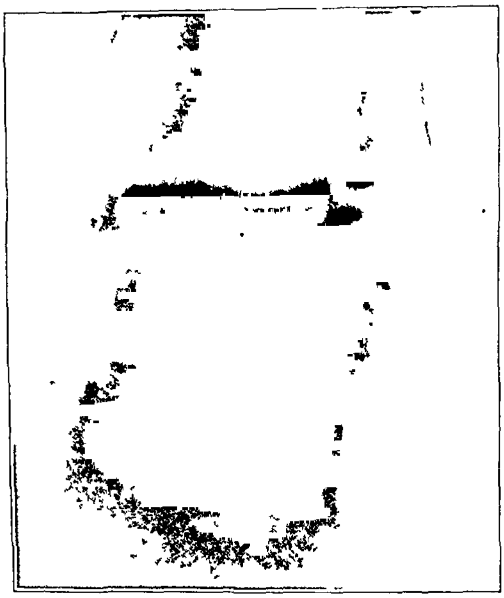

FIG. 2-A

FIG. 2-B

Case 2. Roentgenograms show lesion of osteochondritis dissecans on the superolateral aspect of the talus, adjacent to the lateral malleolus.

Fig. 2-A: In the anteroposterior view the lesion may be seen, but is partially hidden by the lateral malleolus

Fig 2-B: In the lateral view the lesion cannot be demonstrated.

Fig. 2-C: The location, size, and extent of the lesion can best be demonstrated in the oblique view.

FIG. 2-C

chondral fragment; softening of this area readily demarcates the periphery of the lesion. Upon incision of the cartilage at the circumference of the lesion, the involved portion usually becomes separated very readily from the body of the talus, leaving a somewhat sclerotic-appearing excavated base. In the moderately advanced case, there is frequently an overhanging cartilaginous lip; but, if the process has progressed to the point of separation of the loose fragment, the base may be saucerized spontaneously. The loose fragment is covered by smooth articular cartilage on one surface, and there is a thin layer of subchondral bone beneath the cartilage. Microscopic examination discloses a viable, although somewhat fibrillated, hyaline cartilage; the subchondral bone is of decreased vascularity

FIG. 2-A

Case 1, M. W. Roentgenogram of fracture at time of admission. Line of fracture is seen to extend upward in axis of neck of femur, midway between lesser and greater trochanters. This is the exact reverse of the so-called intertrochanteric fracture of the femur.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Shows fracture four months later, after treatment in Russell traction. Callus formation may be seen.
Fig. 2-C: Lateral view of fracture.

extensive surgery and prolonged convalescence, the simple soft-tissue approaches are to be preferred. However, the approach used should be determined carefully before operation by exact location of the lesion, roentgenographically. If the soft-tissue approach is considered inadequate, the more extensive procedure should be employed without hesitation.

Operative Procedure: In the well-established case, simple removal of the separated fragment is all that is necessary, since the remaining defect has usually been filled in and presents a smooth surface. The remaining defect in the talus should be saucerized if there is an overhanging cartilaginous lip, and all loose cartilaginous fragments should bė excised. Careful exploration of the joint for loose bodies should be done routinely.

POSTOPERATIVE TREATMENT

Postoperative immobilization is dependent upon the type of approach used, and is unnecessary unless an osteoplastic or tendoplastic procedure is employed. Similarly, weight-bearing and active motion are allowed as soon as the healing of the operative trauma permits. If a purely soft-tissue approach is used, active use of the part is usually begun within from ten to fourteen days. Postoperative physical therapy is not required, but whirlpool baths and supervised active motion may hasten convalescence.

PROGNOSIS

The prognosis in cases of osteochondritis dissecans of the talus is dependent, of course, upon the stage of the disease at the time the diagnosis was made and the operation was performed. In early cases, without actual separation of the osteochondral fragment and without arthritic changes, the prognosis is excellent. If arthritic changes have developed, or if actual separation of the fragment has occurred, there is greater likelihood of permanent traumatic articular damage with residual disability. It is conceivable that, should articular damage be extensive, arthrodesis of the ankle might be required. Although the authors have not seen a case of such severity, an extensive case involving the talus was described by Schnaberth, who employed arthrodesis as the treatment of necessity.

Fig. 3-A

Fig. 3-B

Case 3. Anteroposterior roentgenograms show small lesion of osteochondritis dissecans at the superomedial articular surface of each talus.

Fig. 3-A: Film of right ankle, taken for comparison at time patient was examined.

Fig. 3-B: Film of left ankle was taken because of pain and tenderness of three years' duration, localized just anterior to the medial malleolus.

be obtained, because she was irrational and confused. No previous history of accidents or operations could be elicited.

Physical examination showed a very thin, frail, weak woman, lying in bed in a Thomas splint.

Roentgenograms at the time of admission showed what was called by the roentgenologist a comminuted intertrochanteric fracture of the neck of the femur, or an oblique axial subcervical fracture of the femur. The position of the fragments was good; the limb was in a Thomas splint. Her general condition was poor. Russell traction was applied for three days and then discontinued, because the patient became much weaker. Because of this fact an elastic bandage was used as a spica; and on the fourth day she was put in a wheel chair, since it was felt that she would die if allowed to stay in bed. It was difficult to get her cooperation because for over a month she was confused mentally and, in addition, she did not understand English. She was discharged with a coxa vara deformity. She would not use her caliper splint, but at the end of four months she gradually gained in strength and was able to walk with a limp, using one crutch. Internal fixation would have produced better results in this case, if it had been possible to get the patient's consent for such an operation and her cooperation (Figs. 3-A and 3-B).

Case 3.* A. R., an Italian woman, sixty-eight years of age, who had been troubled with diabetes and arthritis for several years, gave the following history: In October 1943, while she was rising from a chair, the patient made a slight turn; in doing so, her left lower extremity slipped from under her and snapped.

The patient was treated by Russell traction for three months, and during this time there was evidence of callus formation (Fig. 4). She also showed generalized arthritis, which was especially marked in her hands and feet. At the end of six months she was able to walk without a brace, but she had two to three inches of shortening of her left lower extremity. A pressure ulcer developed over her left Achilles tendon, which had not healed in a year.

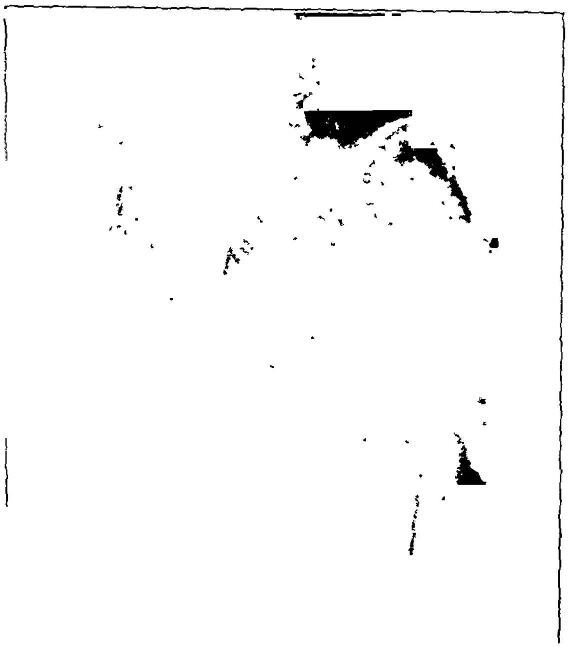

Fig. 4

Case 3, A. R. An atypical reverse intertrochanteric fracture. Patient was treated in Russell traction for three months.

One significant feature of these cases is the fact that, in spite of the age of these women, all showed marked callus formation.

* This case is presented through the courtesy of Angelo A. Zingaro, M.D. The patient was observed by him in private practice, and she presented a fracture that was in many ways similar to a reverse intertrochanteric fracture. It was not typical, however, the fracture line extending farther down on the femur.

Osteochondritis Dissecans of the Talus

(Continued from page 706)

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illness, the patient had had intermittent aching pain in the ankle, not related to walking or weight-bearing. There was no known history of trauma. Physical examination was not remarkable, except for localized tenderness over the talus, just anterior to the medial malleolus. The results of routine laboratory studies were within normal limits. Roentgenograms disclosed a flat elliptic loose body, lying in an excavated area at the medial aspect of the superior articular surface of the talus.

Arthrotomy of the ankle, by the method of osteotomy of the medial malleolus, was done on April 18, 1944. The osteochondral loose body was removed readily; the malleolus was replaced and held with a single screw; and the soft tissues were closed in layers. The postoperative course was entirely uneventful. The pathological diagnosis was "articular osteochondral loose body". This patient was discharged from the hospital on May 29, 1944, and was seen in the Out-Patient Clinic until December 1945. Roentgenograms, taken in November 1945, showed solid union at the site of osteotomy, with no demonstrable arthritic changes being present. On examination, the patient had a full range of motion in the ankle with no crepitus or swelling. He did, however, complain of mild aching pain with changes of weather or after prolonged standing or walking.

Case 7: This patient, a white policeman, twenty-eight years old, had had no trouble with his right ankle until May 19, 1946, when he stepped off a street car onto an irregularity in the pavement, forcefully inverting the left foot against the ankle. On May 20, a diagnosis of fracture of the talus was made by his local doctor, and a plaster-of-Paris boot cast was applied under anaesthesia. The patient had a great deal of pain in the ankle while in the cast and, on June 8, the cast was removed, and one of the authors (R. B. R.) was called into consultation. Examination at that time showed moderate oedema with pitting (one plus) over the dorsum of the foot. Marked pain was present about the anterior portion of the ankle joint, particularly on the medial aspect, with exquisite tenderness over the superomedial portion of the talus just lateral to the medial malleolus. There was slight pain associated with stretching of the lateral ligaments. Inversion of the foot caused pain in the medial portion of the ankle joint, over the site of tenderness in the talus. All motion of the ankle and toes was limited 50 per cent. by swelling; subtalar motion was approximately normal. Roentgenograms in the anteroposterior, lateral, and oblique planes demonstrated the typical lesion of osteochondritis dissecans; an osteochondral loose fragment, one by one centimeter, was lying in a defect at the superomedial pole of the talus (Figs. 4-A, 4-B, and 4-C). The base of this defect was sclerotic, with the osteochondral fragment apparently lying loose in this bed. The patient was treated by contrast baths, elevation, and active and passive motion, without weight-bearing, until there was no swelling about the ankle and the circulatory status of the foot and ankle had returned to approximately normal.

On July 9, 1946, the right ankle joint was explored by the authors' osteoplastic transmalleolar approach. A typical lesion of osteochondritis dissecans was found at the superomedial pole of the talus; the loose

Fig. 4-D

Fig. 4-E

Fig. 4-D: Postoperative anteroposterior view, showing excavated area in talus at site of removal of loose fragment, and reapposition of medial malleolus after osteoplastic approach.
Fig. 4-E: Lateral view shows screw fixation after medial osteoplastic approach.

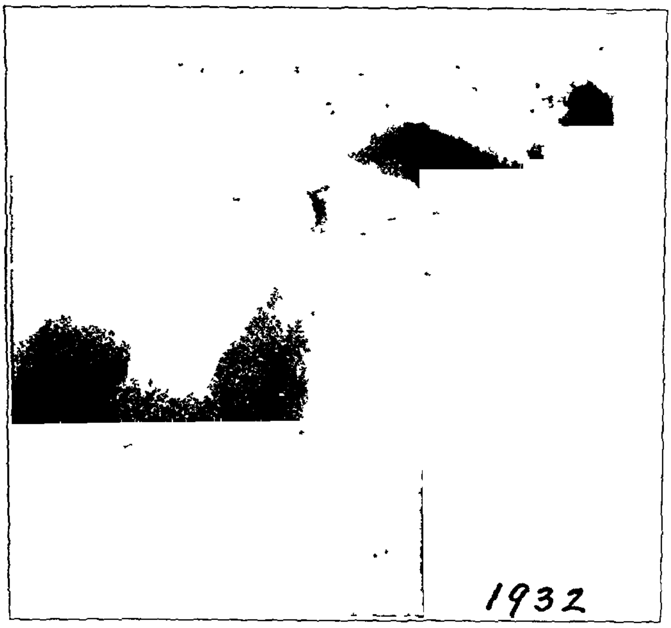

Fig. 1-A

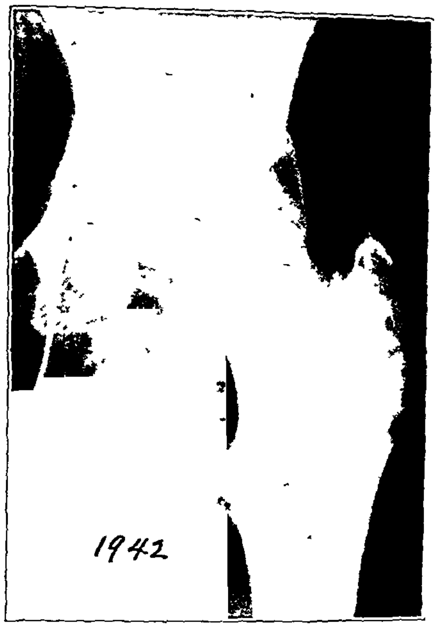

Fig. 1-B

Fig. 1-A: P. Z., 1932. Preoperative roentgenogram at end of traction stage. Second operation was performed on December 5, 1932.

Fig. 1-B: P. Z., 1942. Roentgenogram ten years after operation. When last seen the patient had a normal range of motion and no shortening. Note restoration of the architecture of the hip joint following arthroplasty.

ARTHROPLASTY OPERATION

There have been no essential changes made in the method since it was published riginally in 1932.

The first stage consists of demonstrating that the head of the femur can be pulled own to the level of the original acetabulum. Whether this can be done manually and hecked by a "push-pull" roentgenogram, or whether a preliminary period of skin traction

Fig. 2-A

B. A., 1935. Preoperative roentgenogram. Traction was used for three weeks before the second stage of the operation was performed on October 25, 1935.

TABLE I

Findings in Thirteen Cases of Osteochondritis Dissecans of the Talus, Involving Fourteen Ankles

Case No.	Sex	Age	Occupation	History of Trauma	Duration of Symptoms	Location of Lesion	Operation
1	Male	24	Soldier	Recurrent sprains	3 years	Medial (right)	No
2	Male	22	Pilot	Sprain	3 years	Lateral (left)	No
3	Male	27	Mess officer	Frequent sprains	3 years	Medial (right and left) (Bilateral involvement)	No
4	Male	24	Navigator	Sprain	4 years	Medial (right)	No
5	Male	19	Military police	Direct trauma	2 years	Lateral (left)	No
6	Male	34	Radio operator	None	2 years	Medial (right)	Yes
7	Male	28	Policeman	None	2 months	Medial (right)	Yes
8	Female	26	Red Cross worker	Severe sprain, 13 years before	2 years	Medial (left)	No
9	Male	21	Prisoner of war	Direct trauma	10 months	Medial (left)	Yes
10	Male	23	Pilot	Sprain in plane crash	8 months	Medial (right)	Yes
11	Male	19	Aviation mechanic	Recurrent sprains	1 year	Lateral (right)	Yes
12	Male	24	Pharmacist	None	2 years	Medial (left)	Yes
13	Male	20	Infantryman	None	6 months	Medial (right)	No

was involvement of the right ankle in eight cases and of the left ankle in six cases, there would seem to be no more likelihood of the lesion appearing on one side of the body than on the other. Of the fourteen ankles involved, three lesions were located on the superolateral aspect of the talus; in eleven cases the site of involvement was on the superomedial articular surface of the talus. In one case there was bilateral involvement, with the lesions located on the superomedial aspect of each talus, adjacent to the medial malleolus. In six of the cases, operation was performed. That surgical intervention was not employed in more cases was due to several factors. Some patients did not desire operation and, since most of these cases occurred among military personnel, surgical intervention was not employed, because of existing Army regulations which prohibited operation in long-standing cases.

DISCUSSION

The authors have reviewed the literature since 1941 on osteochondritis dissecans of the talus. Mensor and Melody in 1941 accumulated a total of twenty cases, including one of their own. Since 1941, nine additional cases have been reported. The paucity of these cases would seem to indicate that the condition is rare. During the past four years, however, the authors have seen a total of thirteen cases with involvement of fourteen ankles, and have roentgenograms of three additional cases seen by Eberhard, indicating that the condition, although uncommon, is certainly not rare. All of Eberhard's cases were in the superolateral articular surface of the talus and, if included with this series, would present a total of seventeen cases, with the lesion in the superomedial portion of the talus in eleven cases and in the superolateral location in six instances. With the condition in mind and with careful roentgenographic study, it is probable that the diagnosis will be made with increasing frequency.

Anteroposterior and lateral views do not always reveal the lesion. Careful oblique views will often expose a lesion, hidden by one of the malleoli. Tomography or laminagraphy, although an adjunct in making the diagnosis, is not necessary routinely. A patient presenting a typical history of repeated sprains, with localized tenderness over the anterior

or skeletal traction applied to the affected extremity is required, while the opposite side is immobilized in a plaster spica, depends upon the individual case. However, complete relaxation of the soft tissues *must* be obtained, before the child is considered ready for the second stage. With some of the older patients, it has been found useful to stretch the hip thoroughly by the manoeuvre of straight-leg raising and abduction, with or without subcutaneous adductor tenotomy, before applying moleskin traction or skeletal traction. At examination, the degree of telescoping or laxity varies considerably; and, while not altogether dependent upon age, this is an important factor. If, however, the head of the femur is not brought down at least near the level of the original acetabulum before the second stage or open reduction is attempted, too much tension and too much force will be required at the second stage to reduce the head of the femur gently.

The second stage consists in exposing the hip joint by the lateral approach. The incision begins a finger's breadth posterior to the anterior superior spine of the ilium, curves downward, and crosses the shaft of the femur several inches below the tip of the greater trochanter. After the fascia has been divided and the tensor fasciae femoris has been retracted medially, the muscles attached to the greater trochanter come into view. The tip of the greater trochanter, to which are attached the abductor muscles, is cut through, and the capsule is easily separated by scissor dissection from the overlying group of muscles. The isthmus or hourglass contraction of the capsule can often be identified then. The capsule is divided at its narrowest point, and the head of the femur is inspected. The head is frequently found to be acorn-shaped or even normal in appearance, but it may be quite flattened and deformed. According to Wolff's law, the contour of the femoral head may later be restored to a remarkable degree by activity; yet, when the head is greatly deformed, the prognosis for full function must be guarded. By external rotation of the shaft of the femur, the capsular-covered head can be separated from the muscles posterior to the capsule. While the head is inspected, its cartilage is left intact, and no effort what-

Fig. 3-A

D. R., 1935. Preoperative roentgenogram of an unstable right hip that passively slipped in and out of place. The left femoral head is securely in place, but the acetabulum is poor. Arthroplasty was performed on the right hip.

OBLIQUE SUBCERVICAL (REVERSE INTERTROCHANTERIC) FRACTURES OF THE FEMUR

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The purpose of this paper is to describe a rare fracture that may be termed an "oblique subcervical intertrochanteric" or "reverse intertrochanteric" fracture of the femur. This fracture has been seen before, but has never, to the author's knowledge, been described or recognized as a separate, definite entity. In Harlem Hospital, two cases have been observed during the period from 1937 to 1946 (eight and one-half years), during which time the records show that five patients with pertrochanteric fractures and 177 patients with intertrochanteric fractures were treated.

The fracture may be described as one that begins at the lower border of the base of the neck of the femur and extends obliquely downward and outward between the two trochanters, in the long axis of the neck of the femur. The fracture line would bisect at almost a right angle the line of the more usual and frequent intertrochanteric fracture (Fig. 1).

A careful search of the available literature and of numerous standard textbooks failed to disclose an exact description of this fracture. It is important to describe the fracture separately from other fractures in this area because the mechanics involved, which have a distinct bearing upon treatment, are different. The physio-anatomical factors which deserve consideration in this connection are: (1) The fracture line begins between the two limbs of the iliofemoral or Y ligament, the upper limb of the ligament being attached to the upper fragment and the lower limb to the lower fragment. (2) The muscles attached to the greater trochanter do not influence in any way the movement or position of the distal fragment. In addition to the attachment of the lower limb of the iliofemoral ligament, the iliopsoas is attached to the lesser trochanter and tends to draw the lower fragment upward and inward underneath the neck and head of the femur. In fact, the mechanical arrangement is such as to produce in effect the same results as a low subcervical osteotomy in the same axis as the neck of the femur.

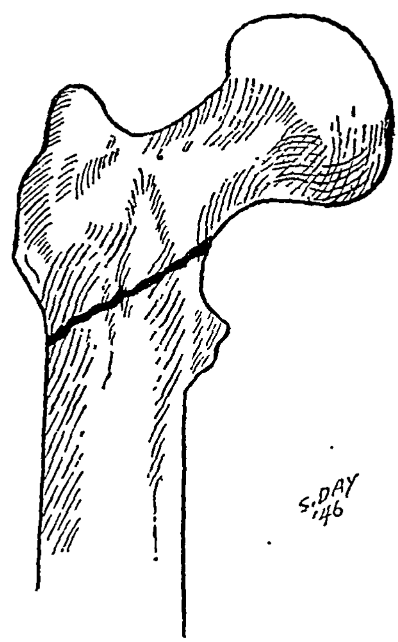

FIG. 1

Drawing of a reverse intertrochanteric fracture.

This fracture is produced by indirect violence, with the thigh in the position of hyperextension, in a patient with muscular and ligamentous weakness and increased bone brittleness. Its infrequent incidence is more clearly understood when we realize that it traverses the femur against its reinforcing cancellous lamellae and calcar femorale.

The term intertrochanteric fracture is used because these fractures follow the anatomical intertrochanteric lines of the upper end of the femur. The fracture under discussion is, in fact, an axial subcervical intertrochanteric fracture, with the fracture line extending obliquely downward to the cortex, as a prolonged extension of the lower border of the neck of the femur. For this reason, the term reverse intertrochanteric fracture probably describes the condition better than any other concise phrase.

soever should be made to reconstruct the head. The capsule is closed over the head by several interrupted catgut sutures, and the remaining or proximal portion of the capsule about the rim of the old acetabulum is removed as completely as possible. With the limb rotated externally and adducted sharply, the site of the original hip socket can be easily identified, inspected, and palpated. With a large curette or a Doyen reamer, a capacious

FIG. 4-A

D. K., 1933. Preoperative roentgenogram. Note deformed appearance of epiphysis and poor acetabulum. Arthroplasty was performed on January 15, 1934.

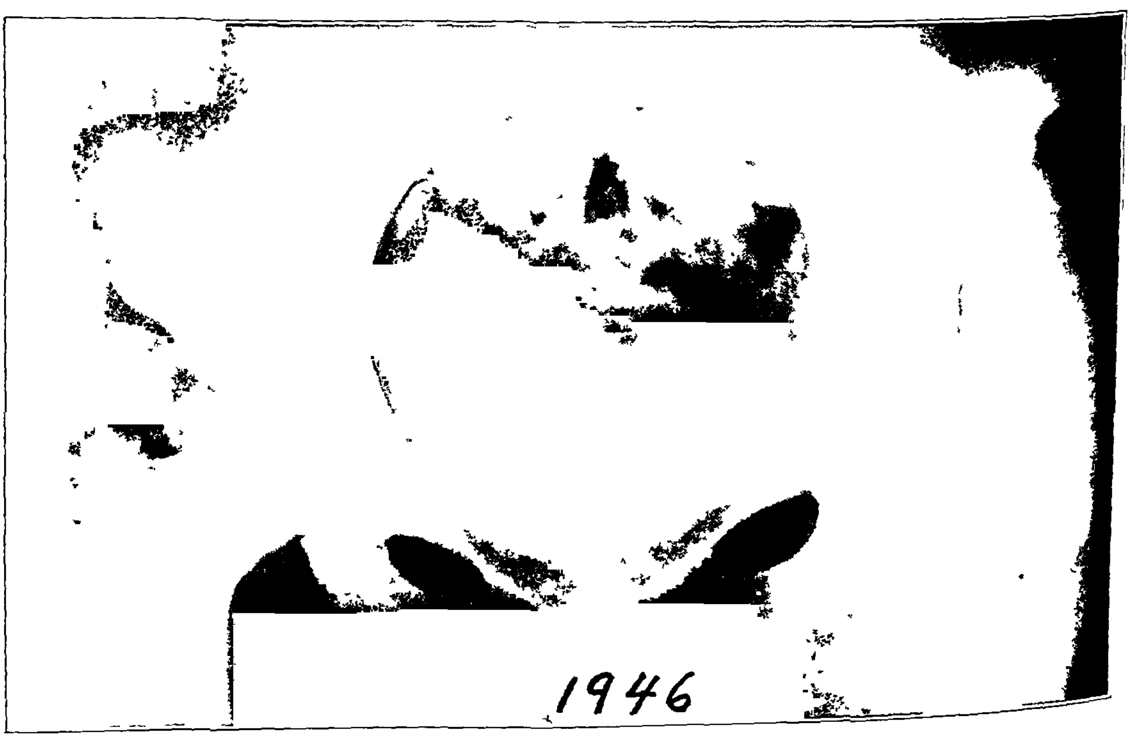

FIG. 4-B

D. K., 1946. Anteroposterior view thirteen years after operation. Note how capital epiphysis has become well rounded, although not perfectly normal in appearance. Hip joint is well reconstructed at level of normal side. There is excellent range of motion.

REPORT OF CASES

CASE 1 (Hospital No. 221,599). M. W., *a negro woman, aged sixty years,* was admitted to the Harlem Hospital on September 12, 1944. Her chief complaint was that she had slipped and hurt her right lower extremity.

The patient had had infantile paralysis when she was a child, which affected her right lower extremity. She had been lame on this side for some months, and at one time could not walk on the leg. She did not know when she became able to walk, but after finishing high school she was able to do so. There had been no previous operations or other accidents.

At ten o'clock on the night of admission, the patient slipped and fell to the floor, striking her right hip, after which she suffered severe and continuous pain in the region of the hip. This pain was particularly marked on motion.

Physical examination showed an obese woman, lying in bed in a Thomas splint. There was tenderness around her right hip joint. Roentgenograms disclosed a fracture of the femur, which began at the junction of the lower border of the neck and extended obliquely downward and outward to the cortex,—a reverse intertrochanteric fracture. It bisected at practically a right angle the intertrochanteric line on that side.

The lower extremity was put into Russell traction. On December 1, 1944, the patient's general condition was good; she could rotate the limb but could not raise her heel from the bed; there was slight limitation of motion of the ankle joint. On January 1, 1945, roentgenograms showed that the distal fragments were slightly displaced medially; but bony union was present roentgenographically, and the patient could move her limb in all directions. She was discharged from the Hospital with a walking caliper splint, on January 12, 1945 (Figs. 2-A, 2-B, and 2-C).

CASE 2. B. B., a Spanish woman, aged seventy-six, was admitted to Harlem Hospital on January 5, 1945. She stated that, on the day before admission, she fell forward while going down some steps. She was unable to get up after the fall, because of intense pain in her right hip and vagina. No further history could

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2, B. B. Subcervical or reverse intertrochanteric fracture of the femur. Extremity was in Thomas splint at the time patient was admitted to the Hospital.

Fig. 3-B: Shows position of fragments four and one-half months later. Patient had been treated by only an elastic spica around her hip. Marked callus formation is present. The lower fragment has been pulled inward and upward, while the upper fragment has been pulled outward. The result in this case is similar to that of a subtrochanteric osteotomy without internal fixation.

in these younger children, attempts at closed reduction should first be made, and arthroplasty should be reserved for those hips in which closed reduction has not been successful

Children from Three to Ten Years of Age

In patients over the age of three, both soft-tissue changes and fundamental osseous maldevelopment make attempts at closed reduction increasingly difficult. Not only do the abductors and adductors become shortened and contracted, but the blood vessels and nerves also show accommodative changes. In addition, the auricular-like depression on the side of the ilium begins to form, and the head of the femur becomes more acorn-shaped or flattened, as it gravitates upward and backward. This displaced femoral head drags along the capsule, which becomes greatly thickened on its superior surface and assumes an hourglass appearance as it becomes elongated. The telescoping, which indicates relaxation of the soft tissues about the hip, varies somewhat in different individuals, but it usually becomes less as the child grows older and as the dislocated hip becomes bound in its position of dislocation through weight-bearing.

CONTRA-INDICATIONS FOR ARTHROPLASTY

As the first stage in the procedure advocated consists in meticulously stretching the soft tissues and producing a relaxation about the affected hip, it is obvious that the factors of age and weight-bearing will ultimately produce so much shortening of the soft-tissue components that the head of the femur cannot be pulled down opposite the acetabulum without running the risk of damaging these structures. It is difficult to limit the operation in children wholly on an age basis, for there are individual differences in soft-tissue relaxation; but from past experience, it is the opinion of the author that the operation discussed here should not be attempted in children over the age of ten for unilateral dislocations, or over the age of eight for bilateral dislocations. Although we have been able to obtain sufficient stretching during the first stage in children over ten to permit us to force the head into the acetabulum which has been reconstructed at the normal level, we have seen aseptic necrosis of the femoral head later develop in these older children. We have all observed that bone tissue within certain limits of stress and strain is a malleable,

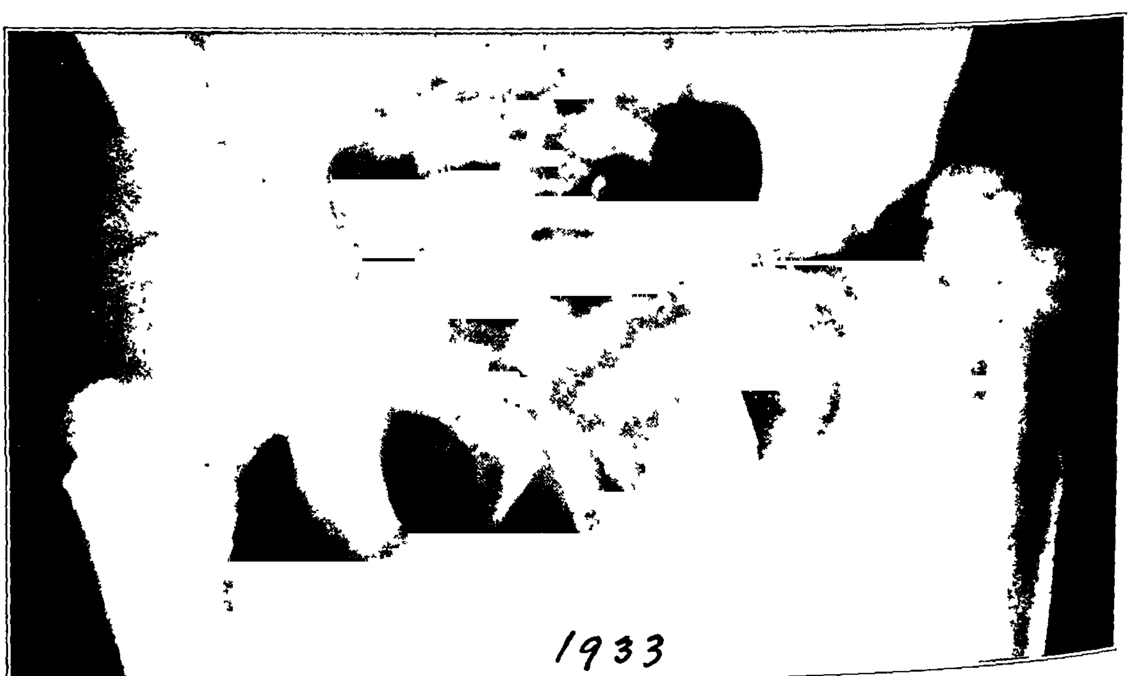

FIG. 5-A

A. Y., 1933. Preoperative roentgenogram. Two weeks of traction was followed by the second stage of operation on May 5, 1933.

ARTHROPLASTY OF THE HIP FOR CONGENITAL DISLOCATION IN CHILDREN*

BY PAUL C. COLONNA, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedic Surgery, University of Pennsylvania Medical School, Philadelphia

The primary purpose of this paper is to present an end-result study of an arthroplasty procedure, devised some years ago for treating congenital dislocation of the hip. There are certain indications for its use, and also contra-indications which should be stressed, as well as postoperative safeguards, which should be borne in mind in the care of patients undergoing this operation. Naturally, the author has been keenly interested not only in observing the functional results in patients operated upon ten or more years ago, but he has also been anxious to satisfy himself by repeated follow-up roentgenograms that the reconstruction of the originally deficient acetabulum has been retained as to size and depth, and that a practically normal joint space has been preserved over the years.

Twenty-five years ago, rather brutal and traumatizing methods of bloodless reduction were in vogue. The comparatively gentle methods of closed reduction, generally accepted and practised today, represent great progress in the treatment of this congenital anomaly. The range of painless motion that can be obtained by closed reduction today, in those cases in which reduction has been effected within the first few years of life, is adequate proof of the value of gentleness in using the so-called bloodless method. It is hoped, therefore, that this gentleness will be emphasized in teaching the technique to the younger orthopaedic surgeons, and that this teaching will result in a smaller number of patients with permanent stiffness, arthritic changes, or aseptic necrosis of the femoral head. On the other hand, an open reduction can be an even more gentle procedure and can be far more desirable than one attained by closed methods employing force and awkwardness, which may, however, appear satisfactory roentgenographically. Reduction alone is of doubtful value, if it results in a painful or almost stiff hip.

Undoubtedly our attention to this whole problem has, heretofore, been centered too much upon the bony components of the deformity and too little upon the soft-tissue changes present. It should be remembered that roentgenograms do not show bruised or contused muscles, the hourglass constriction of the capsule, or contraction of the abductor and adductor groups of muscles. These are formidable barriers to gentle reduction. In many of these cases, adequate preliminary traction should be an absolute prerequisite to any attempt at actual reduction, either closed or open.

The aim of the orthopaedic surgeon in treating congenital dislocation of the hip should be, first, gently to obtain an accurate anatomical reduction. This means that the head of the femur should be brought not only downward, but forward in relation to the sagittal plane of the body. Second, stability and an excellent range of motion should be the end result; and, third, the relationship of the head and acetabulum, as demonstrated by follow-up roentgenograms over a long period, should show development of the bony components progressing in a normal manner.

The arthroplasty operation reviewed here has already been described by the author, and the reader is referred to these previous articles. This paper deals with the posterior type of congenital dislocation, but the principle of the arthroplasty is also suitable for cases with anterior types of congenital dislocation. The technical aspects, the indications for use, and the postoperative care will be only briefly reviewed, with follow-up roentgenograms, made ten to thirteen years after operation in five of the early cases.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1947.

accommodative substance, but articular cartilage and bone undergo aseptic necrosis, if subjected to a continuous abnormal pressure. Therefore, some type of osteoplastic buttress or a shelf operation is more desirable in older children.

POSTOPERATIVE CARE

When the hip is taken out of plaster at the end of four weeks and active and passive motion in bed is begun with the limb suspended, the simple expedient of keeping a pillow between the limbs to retain abduction of 10 to 20 degrees on the affected side has been found adequate to prevent any danger of redislocation. This complication has not occurred in any of our series, but if, upon removal of the plaster, some effort is not made to limit adduction, this could conceivably happen. The author also favors keeping five to ten pounds of traction on the limb during the first few weeks of active movement in bed. If a therapeutic tank is available, the patient should move the limb a part of each day in this medium. The patient should be encouraged to sit up, but in order to prevent the development of any flexion contracture at the hip, the patient should be turned on his abdomen for a part of each day.

From the time the plaster is removed, particularly in the early weeks, the hip must be examined often for the effects of imbalanced muscle pull, particularly from the adductors and flexors. A good deal of functional adjustment has to be made in this reconstructed hip, as in all joints subjected to arthroplasty, and some coddling and watchful attention to details will spell success in the future progress of the hip. Not until a good range of active and passive movement in bed can be demonstrated, and any tendency to adduction and flexion has been corrected, should weight-bearing be permitted. It is difficult to give a time when weight-bearing should be begun, as this would have to be decided upon in the individual cases; but it is safe to say that a minimum of three months, and sometimes as much as six, may elapse from the time of the operation before it is wise to allow the patient to begin putting weight on the hip for limited periods during the day. During the weeks of limited weight-bearing, starting with a few minutes and gradually increasing, the hips must be carefully watched for any signs of stiffness or loss of motion. At the slightest evidence that the hip is "tightening up", the patient must return to bed. Traction for a few days will usually be sufficient to restore the previous range of motion. The use of braces to protect the hip against weight-bearing is not advocated; and only occasionally is a child found cooperative enough to be allowed to be up on crutches in less than three months, to bear weight on the normal side, and to swing the affected hip.

The roentgenograms shown represent five of the early cases which have been followed for many years. They demonstrate that the normal bony architecture of the hip has been restored.

A moving picture shown by the author at the Academy meeting demonstrated these children, ten to thirteen years after operation, walking without a limp and with an excellent range of active and passive movement.

CONCLUSIONS

From this follow-up study of ten to thirteen years, the following conclusions have been reached:

1. This two-stage procedure in the younger age group is permanently effective in providing accurate reduction, stability, and an excellent range of mobility.

2. Careful attention to details must be employed not only in the first and second stages, but also in the early part of the postoperative care.

3. The results have been better with the unilateral than with the bilateral case.

4. The procedure is not to be employed in children beyond the age of ten, while the best results have been obtained in children under eight years of age.

Fig. 2-B

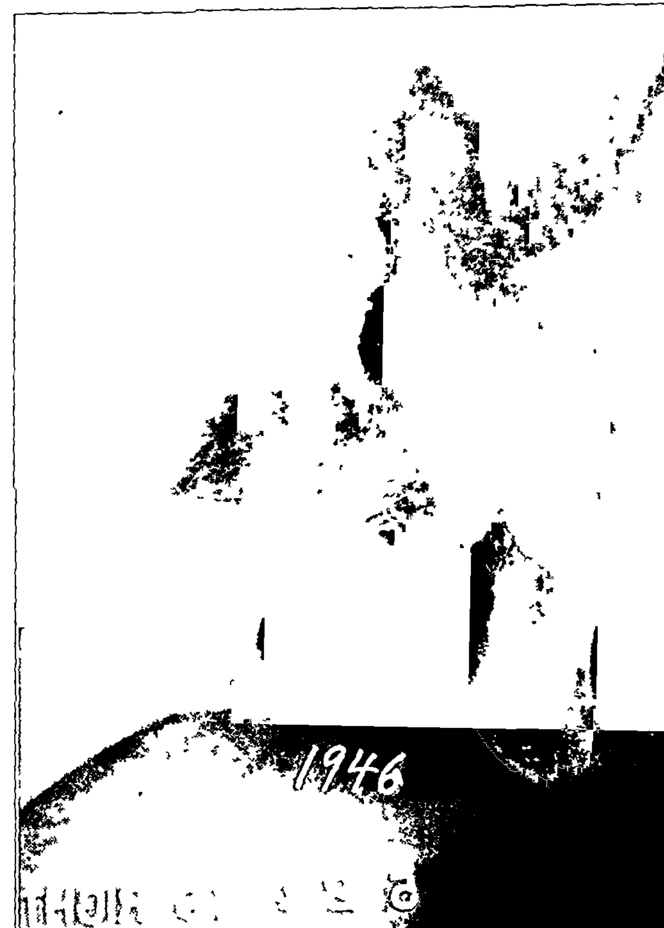

Fig 2-C

B. A., 1916. Anteroposterior and lateral views taken eleven years after operation. Notice well-formed acetabulum and joint space, as well as appearance of head. Patient has normal function.

A study has been made of thirteen patients operated upon at the Oklahoma Hospital for Crippled Children during the years 1938 to 1941. In ten patients, the dislocation was unilateral; and in three cases, bilateral dislocations were present.

Six patients were from two to seven years of age. Seven patients were from seven to eleven years of age. Only one patient with a bilateral dislocation was subjected to an arthroplasty of each hip. In every instance, a period of preliminary traction and stretching of the soft tissues about the hip was carried out. This was continued until the head of the femur was opposite the level of the acetabulum, or as near that point as possible.

A determination of the final results showed three cases (one, a child two years old; one, seven years; and one, eight years of age) which could be classified as excellent results. These patients had no limitation of motion in the hip, no pain, arthritic changes, or shortening, and the hip was stable.

One patient had 10 degrees of limitation of complete extension, but a full range of motion in other directions. No arthritic changes were present, and the hip was stable with one-half inch of shortening. This was considered a good result.

Two cases with some contracture and moderate limitation of motion of the joint, but with no pain or arthritic changes and no shortening, were considered fair results. In six cases, the results were classified as poor. All of these patients were in the older age group,—from eight to eleven years. Arthritic changes, stiffness of the hip, and contractures of some degree were present in all cases. Pain was also a predominant symptom. One patient, aged five, died as a result of shock, following the operation.

This procedure is not usually indicated in children above the age of eight years, or in those cases in which there is difficulty in pulling the head down to the level of the acetabulum.

I believe that the following factors are essential to a successful result:

First, a patient in the proper age group, with a unilateral dislocation.

Second, the reconstruction of a large, well-formed acetabulum.

Third, looseness of the capsule over the head of the femur.

Fourth, complete relaxation of the soft tissues about the hip, so that the head can be replaced in the newly formed acetabulum without tension.

Fifth, careful attention to the details of preoperative and postoperative management.

In no case in which this procedure was carried out, regardless of the final result, was there a redislocation of the hip. We believe, therefore, that this procedure is useful, and that excellent results can be obtained when the prerequisites listed are present.

Dr. Paul C. Colonna, Philadelphia, Pennsylvania (closing): I think this group should be aware of the difficulties which have been encountered in the cases in which the operation is not applicable. It is very foolish to think that this operation is the answer for all congenital hip problems. It is very useful in obtaining stability and restoration of the normal joint architecture within certain age limits.

The point which Dr. Crego brings up—that we cannot see the ultimate result today—is perfectly true. When I first started on this, in 1930, the comment was made: "Wait a little bit, and we shall see." We have presented five cases today, in each of which the operation was performed ten or more years ago; and I hope that I can present these same cases again in another ten years. I think that the procedure is of great value within the age limits prescribed.

If a member presents a new procedure, he should present the end results five or ten years later; and if he has given up the procedure, we should know it. If he has found it successful, we should also know it.

FIG. 3-B

FIG. 3-C

D. R., 1946. Anteroposterior and lateral views taken eleven years after arthroplasty of right hip joint. Note reconstructed acetabulum with normal joint space and well-formed head. Patient has normal motion.

Fig. 3-A

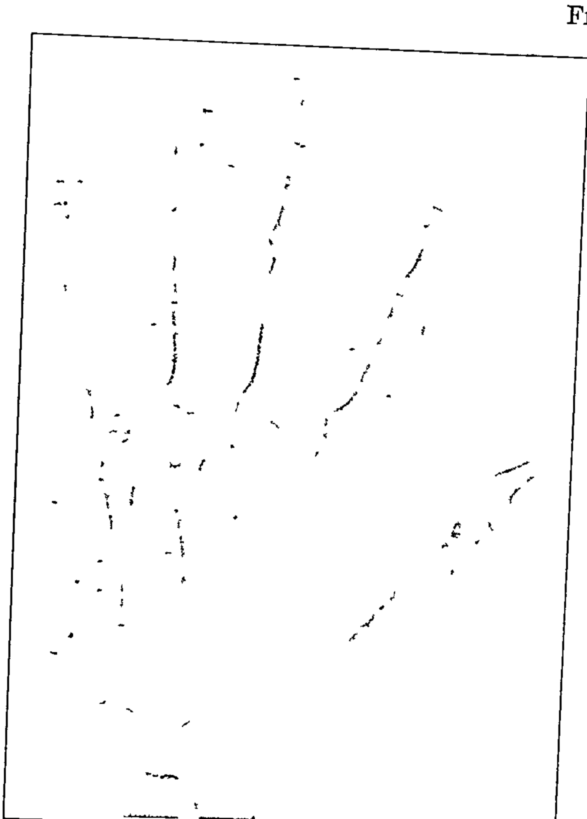

Fig. 3-B

Fig 4

Fig. 3-A: Massive defect involving the first, second, and third metacarpals.

Fig. 3-B: Restoration of metacarpals with doweled tibial grafts. Proximal ends of graft are embedded into carpal bones. Free tendon grafts restored extension to the thumb and fingers. The thumb can be pinched against the index finger and middle finger. The bone-grafting was done in two stages.

Fig. 4: Shows complete loss of the distal three fourths of the second and third metacarpals, with bone grafts stabilizing the proximal phalanges in flexion of 30 degrees.

cavity is then reamed out at the level of the original acetabulum. This point is most easily recognized by identifying the triradiate cartilage which must become the floor of the reconstructed acetabulum. (If the case is a unilateral dislocation, the site of the acetabulum can also be judged roughly by identifying the level of the tip of the greater trochanter or the anterior superior spine of the ilium on the normal side.) It should be pointed out that a remarkably deep acetabulum can be obtained. At this level, the innominate bone is very thick, and when this procedure is done for the first time, the operator is always surprised at the amount of bone that may safely be removed from this site.

The newly made cavity must be large and deep, and its floor must be smooth. When the curetting is finished, there should be a domed and properly sloping superior roof. With gentleness and without the use of a skid, the capsular-covered femoral head is placed deep within this newly made acetabulum, and the limb is placed in abduction of about 20 degrees. *It must be remembered at the time of the open reduction that the capsular-covered head has to be placed deep within the socket.* This may require placing the limb in marked internal rotation. If this becomes necessary, a supracondylar osteotomy with derotation should be done a few weeks later; this has been necessary a number of times, and is indicated whenever the anterior torsion of the neck of the femur appears to make internal rotation necessary. This has not seemed to have any effect on the ultimate function of the reconstructed hip joint.

FIG 4-C

D. K., 1946 Lateral view thirteen years after operation.

No effort is made to suture or to attach to the acetabulum the capsule that covers the head, when it is placed in the newly formed acetabulum. It is believed that the outer surface of this capsule becomes attached firmly within a few weeks to the raw bony walls of the newly formed socket. The greater trochanter, with its attached muscles, is resutured into position. It has not been found necessary to transfix the greater trochanter with a bone graft; rather, a number of interrupted catgut sutures are placed in the soft cartilaginous tissues, and the cut surfaces of the greater trochanter are approximated snugly. The wound is closed in layers. With the hip in complete extension and slight abduction, a unilateral plaster spica is applied from the nipple line to the toes.

INDICATIONS FOR ARTHROPLASTY

Children Under Three Years of Age

The failures that occur following one or more careful attempts at closed reduction in children under three years of age are due mainly to two causes: First, there are a few cases in which reduction cannot be obtained by the closed method; and, second, redislocation sometimes occurs. It may be that a certain number of failures are due to the fact that the surgeon does not interpret properly the postreduction roentgenogram, and he thinks that the dislocation has been reduced when it has not. A great number of failures are due to an obvious interposition of soft tissues or to an insecure, sloping saucer-like acetabulu or to both. Whatever the causes responsible for redislocations, a certain number of t do occur in children, and arthroplasty is considered to be indicated in such ov

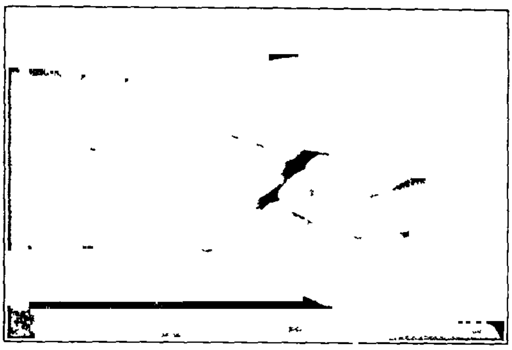

Fig. 5-C

Fig. 5-D

Showing early functional results in same case.

Fig. 6-A

Fig. 6-B

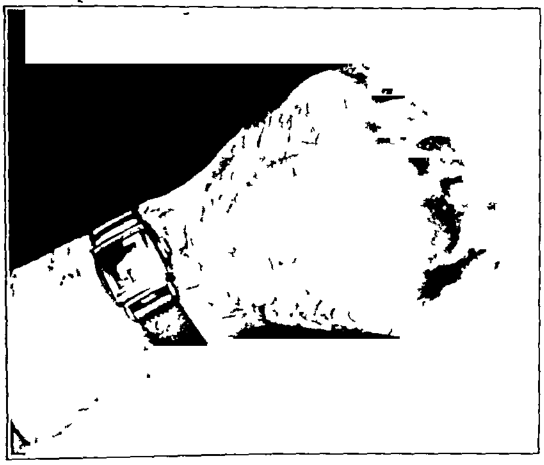

Fig. 6-C

Fig. 6-D

Fig. 6-A: Roentgenogram shows destructive metacarpal fracture with shortened finger and hyperextended metacarpophalangeal joint.

Fig. 6-B: Postoperative view shows some gain in finger length and stabilization of the metacarpal head.

Figs. 6-C and 6-D: Postoperative function in same patient.

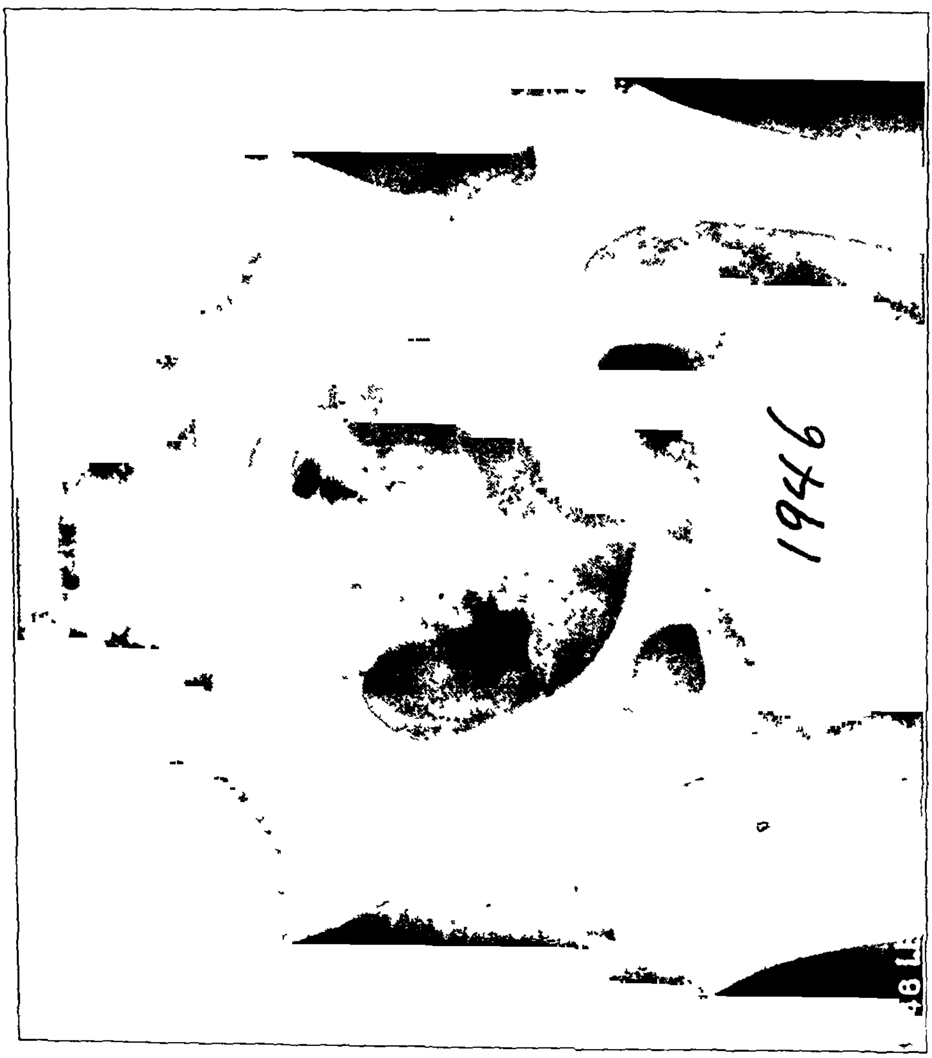

Fig. 5-B

Fig. 5-C

A. Y., 1946. Anteroposterior and lateral views thirteen years after operation. Note restoration of normal joint architecture following arthroplasty. Patient has normal function.

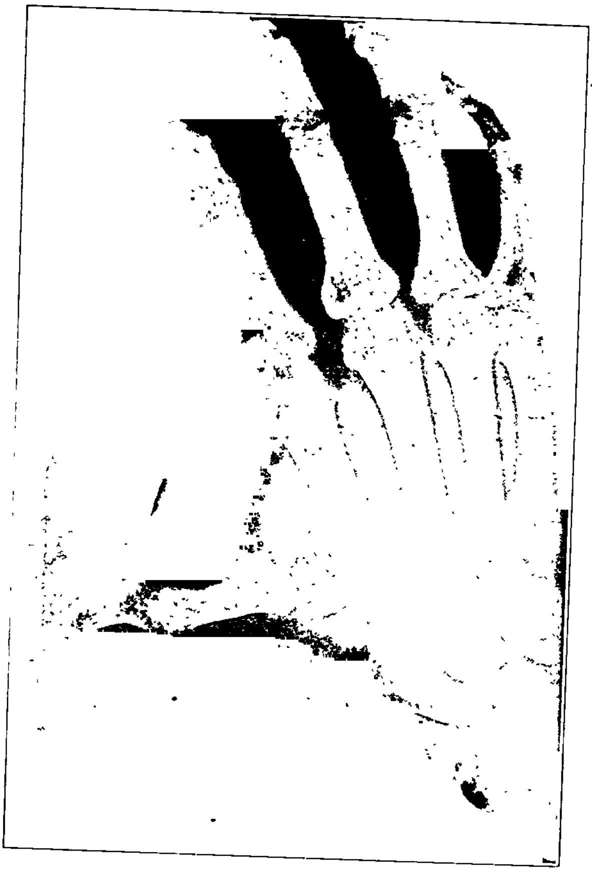

Fig. 9-A

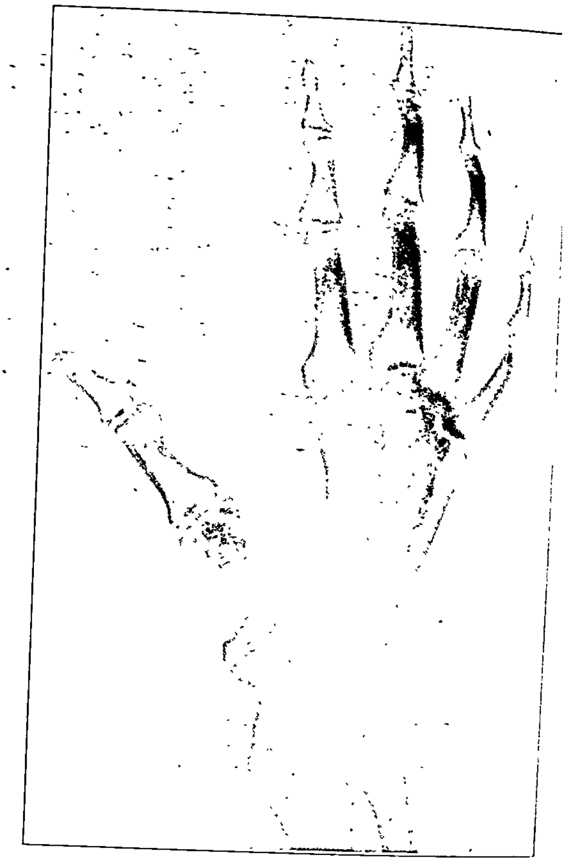

Fig. 9-B

Fig. 9-C

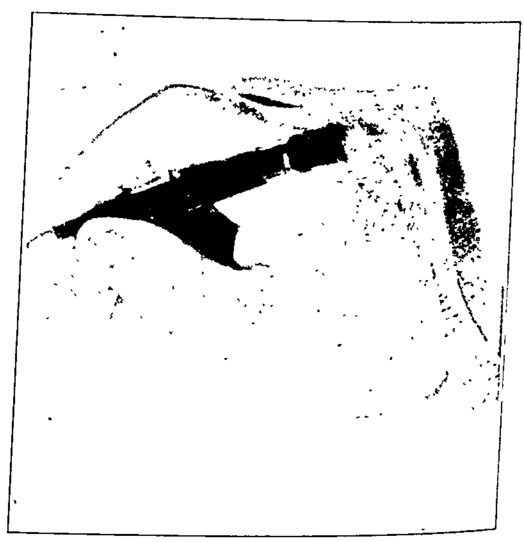

Fig. 9-D

Fig. 9-A: Shows loss of all but the head of the first metacarpal, resulting in a useless thumb.

Fig. 9-B: The graft was inserted into the carpus and the adjacent metacarpal base. Postoperative roentgenogram, taken two years after bone-grafting, shows complete union. Patient can extend fully the interphalangeal and metacarpophalangeal joints of the thumb, and the thumb can be pinched against the index finger, middle finger, and ring finger. His work is assembling typewriters.

Fig. 9-C: Lateral view illustrates functional position of the thumb.

Fig. 9-D: Function possible following a tendon graft for loss of the extensor pollicis longus.

metacarpal or carpal bones (Fig. 2). If only the head of the metacarpal remains, it can be stabilized by extending the graft into the carpus (Figs. 3-A and 3-B); if only the base remains and the digit must be preserved, the graft can be fused to the proximal phalanx at 30 degrees of flexion (Fig. 4). In cases of multiple metacarpal defects, multiple bone grafts usually can be placed in one operation (Figs. 5-A, 5-B, 5-C, and 5-D.)

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DISCUSSION

DR. C. H. CREGO, JR., ST. LOUIS, MISSOURI: It is most difficult to evaluate fairly the results obtained in an operative procedure with which one has had no personal experience. I wish, therefore, to confine my remarks largely to a recapitulation or a restatement of certain basic principles in the present-day treatment of early posterior congenital dislocation of the hip, which have been brought out and emphasized by Dr. Colonna in all of his papers on the particular operation described today.

I am sure we are all agreed that it is in the patient who has not passed the age of six or seven that we can hope for results which approximate normalcy. Even in this group of cases, however, there have been in the past all too many poor results and complete failures from the old, time-honored classical methods of treatment.

What, then, are the basic principles of modern treatment, upon which depend our hope of obtaining more successful anatomical, physiological, and functional end results?

Foremost, in my opinion, is the fundamental fact that the reduction itself should in all instances be accomplished without the use of any force whatever. This, of course, implies the use of preliminary traction of one kind or another. Dr. Colonna considers traction to be a highly important part of his procedure, and I'm sure he will agree that it is an important part of any procedure which aims at reduction without trauma.

This preliminary traction, to be effective, should be sufficient to pull the head down completely, opposite the lower half of the acetabulum; and it should be maintained long enough to prevent recontraction of the soft parts, after the actual reduction has been effected. Only in this way can we completely eliminate not only the trauma incident to the reduction, but also the trauma of the intra-articular pressure following reduction.

I prefer to use skeletal traction in patients eighteen months of age and over, because I have not been able to do an adequate job with any of the various forms of skin traction. Even with skeletal traction, it is frequently necessary to tenotomize the adductors and the hip flexors, before the head can be pulled down completely.

Having been successful in placing the head into the acetabulum without trauma, we are now confronted, in the majority of cases, with developmental defects in the acetabulum which must be corrected. To be content with reduction alone and to leave a shallow acetabulum with a more or less vertical and defective roof, on the assumption that the acetabulum will deepen and reshape itself, is to court certain disaster.

This brings us to the second basic principle,—namely, that if an acetabulum is inadequate, it must in some way be made at least to approach normal. Dr. Colonna has realized this fact, and the procedure under discussion was devised to produce a socket of sufficient size and depth to hold the head adequately in place, and at the same time to preserve motion by the interposition of the capsule between the articular surface of the head and the raw surface of the newly formed socket. You have seen the roentgenograms and the moving pictures of a few of his older cases. That the results are good in the cases shown, there can be no doubt. What will eventually happen to them, no one can predict; but there is no true joint surface on the acetabular side, and for this reason traumatic arthritis may develop later.

The only other alternative in an attempt to produce depth and to restore contour to the inadequate acetabulum is that of acetabular reconstruction. To achieve this, the vertical roof of the acetabulum is turned down and reformed, so as to approach its normal contour; then this iliac bone is packed in firmly above the newly formed roof. This is not a true shelf operation, and should not be considered as such. This particular procedure has the advantage of preserving normal cartilage on the acetabular side of the joint and, to my mind, is more sound physiologically than the arthroplasty.

This brings us to the third and last basic principle,—namely, the correction of the so-called anteversion or femoral torsion. If this deformity exists in any appreciable degree, it should be corrected. It will not correct itself any more than an inadequate acetabulum will correct itself. If left uncorrected, we can expect the head to become redislocated in an anterior direction and eventually to drift upward. Dr. Colonna has not mentioned this phase of treatment, and I would like to know his ideas on the subject.

DR. C. R. ROUNTREE, OKLAHOMA CITY, OKLAHOMA: We believe that the success of the operation which Dr. Colonna has so clearly described depends, first, upon a careful selection of the patients to be operated upon and, second, upon the technical skill of the operator, plus careful preoperative and postoperative management.

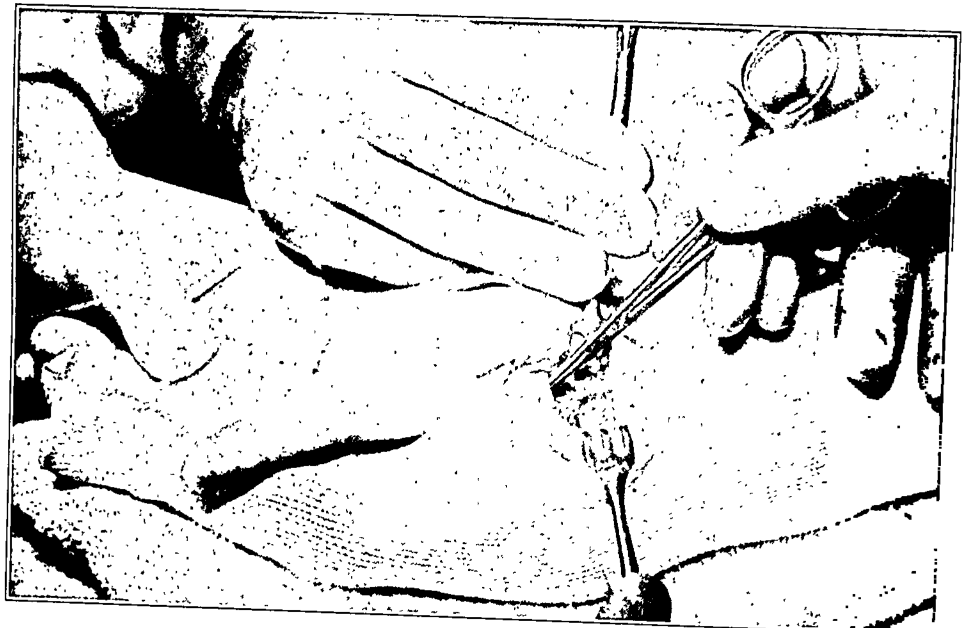

Fig. 12-A
Illustrative case, showing the method of repair.
Fig. 12-A: Preparation of fragments for tibial-bone graft.

Fig. 12-B
Hyperextended metacarpophalangeal joint being flexed. Excision of collateral ligaments is not necessary in this case.

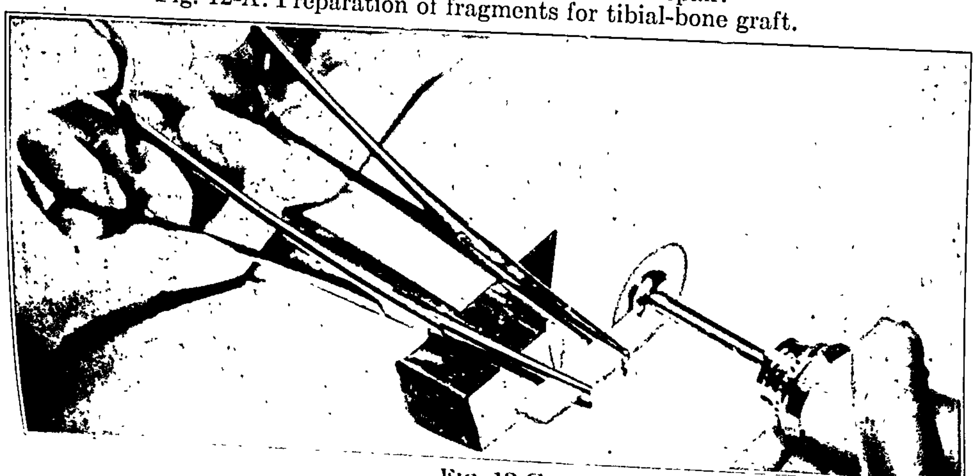

Fig. 12-C
Forming dowel with circular saw

Fig. 12-D
Completed dowel on graft.

METACARPAL RECONSTRUCTION*

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Severe injuries of the hand are frequently complicated by massive metacarpal defects, which can be corrected only by bone-grafting. The goal of reconstructive surgery of the hand is a restoration of function, and to this end an orderly surgical program should be outlined before any definitive reconstructive procedures are attempted. Obviously, if all the component parts of a digit are severely damaged, an amputation is usually indicated. Frequently, other fingers may already have been amputated; and it is, therefore, necessary in these cases to carry out reconstruction procedures, however prolonged, in order to preserve what remains of the hand (Fig. 1).

Prior to correction of the existing bone defects, it is essential to have good skin and subcutaneous tissue on the dorsum of the hand. The time expended in obtaining skin

FIG. 1

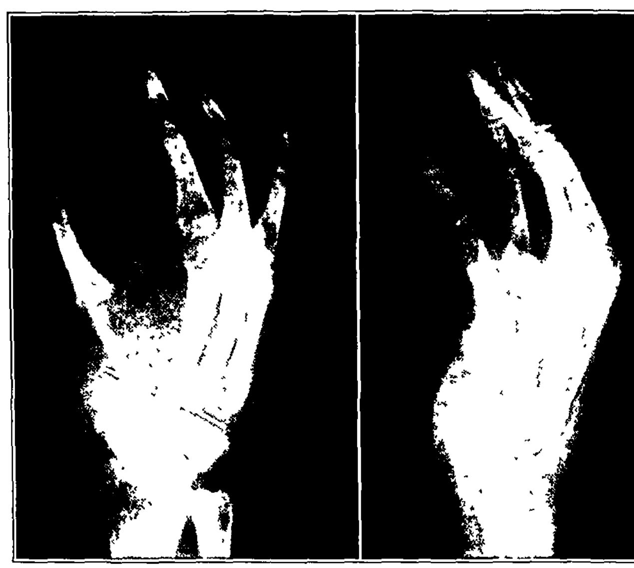

FIG. 2

Fig. 1: Loss of the ring finger with destructive fractures of the second and third metacarpals, bridged by tibial bone grafts. The proximal phalanx of the middle finger has been fused to the graft. Skilled function is possible.

Fig. 2: Transposed index finger for complete loss of thumb. A bone graft, fixed with Kirschner wire, holds the digit in a functional position.

coverage by abdominal pedicle flap or tube is well worth the effort, for the subcutaneous fat thus obtained is invaluable in forming a bed for tendon function and in filling the defects left by scar excision.

The general principles obtaining for grafts of the larger bones are also applicable to grafts of the metacarpals.[1] However, because of their small size, fixation by plate or screws is usually impractical and must be compensated for by more attention to the finer details of what Bunnell calls "bone carpentry". In general, the success of the operation is in direct proportion to the accuracy with which the graft has been fitted to the recipient metacarpal or carpal fragments. Additional fixation, when desired, can be obtained by the use of stainless-steel wire or pins, which can be transfixed into adjacent uninvolved

* Read before the American Society for Surgery of the Hand, Chicago, Illinois, January 24, 1947.

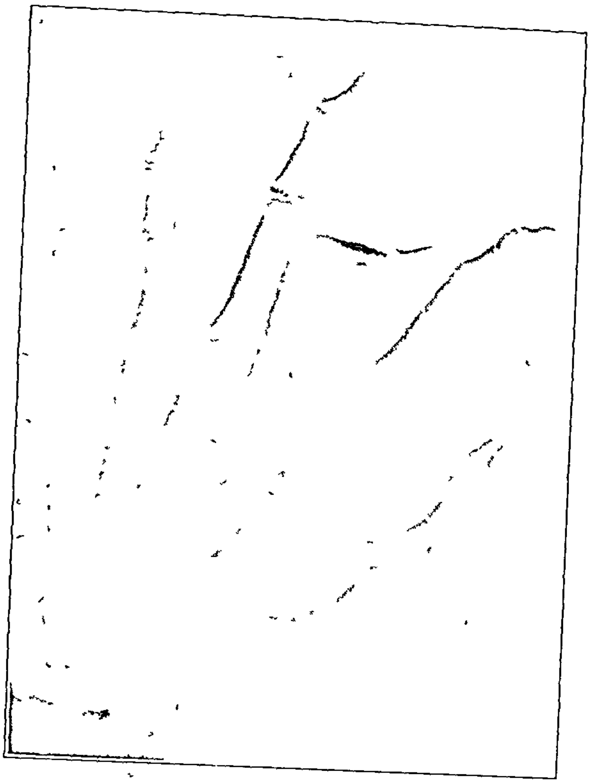

FIG. 12-H

FIG. 12-I

FIG. 13

Fig. 12-H: Roentgenogram of destructive metacarpal fracture, showing typical deformity.

Fig. 12-I: Postoperative roentgenogram, showing moderate gain in length.

Fig. 13: Plaster immobilization of grafted metacarpal, permitting freedom of intact structures. The finger is flexed to 30 degrees at the metacarpophalangeal joint. Active flexion and extension of the interphalangeal joints are possible.

should be made to maintain by early mobilization whatever function remains, for only with all the intact structures functioning satisfactorily can the injured portion of the hand be evaluated properly and the reconstruction program be outlined.

OPERATIVE TECHNIQUE

Exposure of the metacarpal to be grafted is gained through either a longitudinal or a curved incision, depending upon the existing scars and the nature of the resurfaced defect. All scar tissue is dissected from the extensor tendons, care being taken to preserve intact paratenon. The fibrous tissue between the metacarpal fragments is dissected *en bloc*, so that a bed of soft tissue is exposed; it is then possible to regain by traction most of the normal finger length. In most cases, for good results, the proximal fragment must be sacrificed as far as its base, where it is recessed with the osteotome at an angle of approximately 30 degrees (Fig. 11,*a*). The distal fragment is cut transversely with the circular saw or rongeur, and the medullary canal is opened to receive the doweled end of the graft. With traction on the finger, the defect between the metacarpal fragments is measured carefully

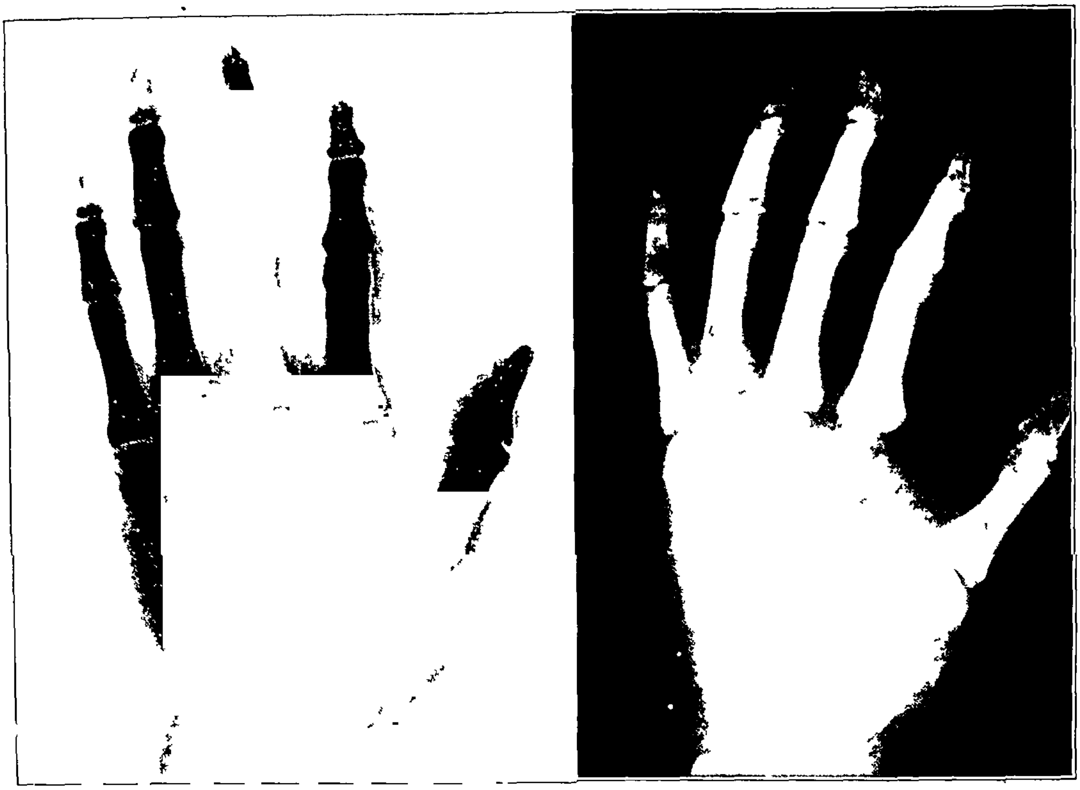

Fig. 5-A
Multiple metacarpal defects are shown.

Fig. 5-B
In early postoperative views, note restoration of the longitudinal palmar arch and the functional position of the thumb.

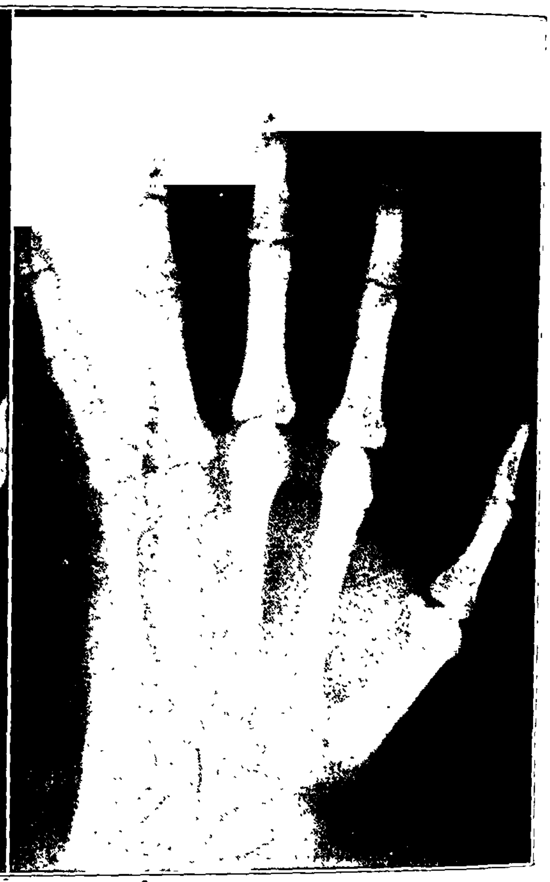

FIG. 16-A FIG. 16-B

Fig. 16-A: Destructive metacarpal fracture of ring finger.
Fig. 16-B: Result following bone-grafting.

FIG. 17-A

FIG. 17-B

FIG. 7-A

FIG. 7-B

FIG. 7-C

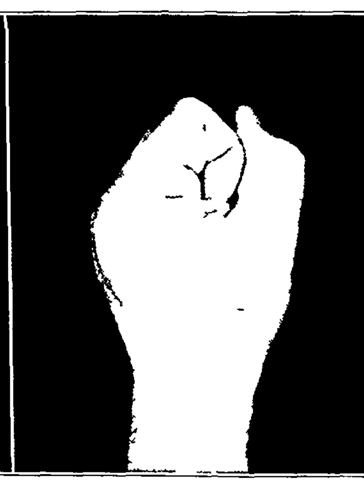

FIG. 7-D

FIG. 7-E

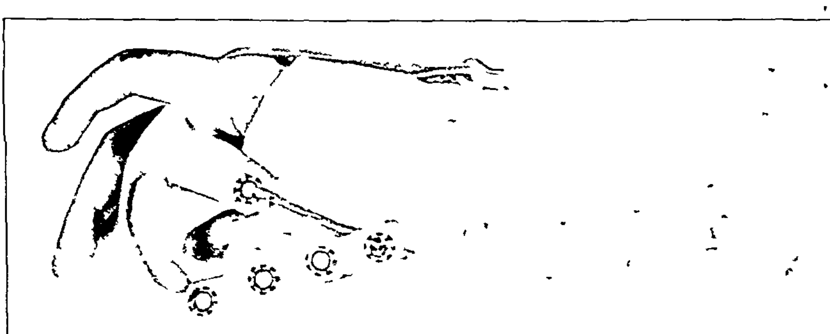

FIG. 8

Figs. 7-A and 7-B: Preoperative and postoperative views show metacarpal reconstruction.

Fig. 7-C: The metacarpal heads have been stabilized through bone- [illegible] ected [illegible] pre- vent flexion of the metacarpophalangeal joints.

Figs. 7-D and 7-E: Range of motion following excision of collateral ligaments.

Fig. 8: Traction splint used for overcoming a tight extensor mechanism. The progressive pull is directed toward the tubercle of the navicular.

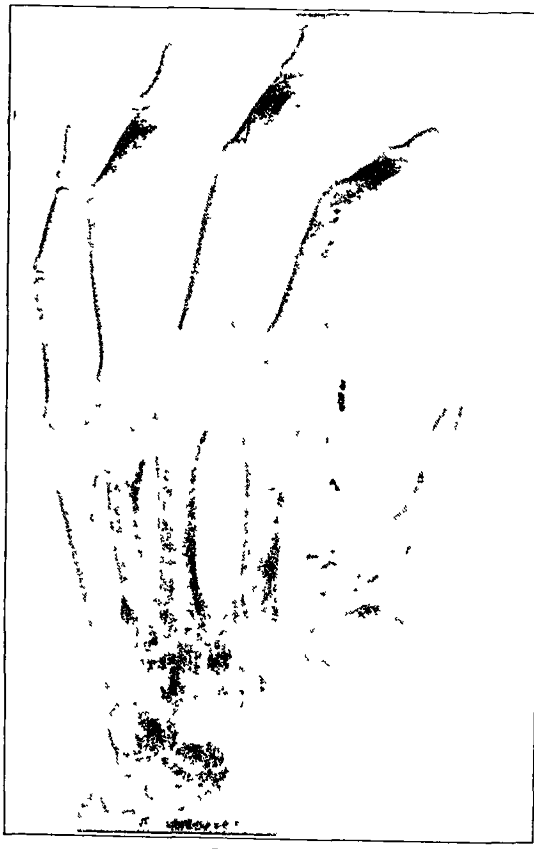

Fig. 18-A

Fig. 18-B

Fig. 18-A: Shows loss of distal thumb metacarpal, with joint involvement.
Fig. 18-B: Defect bridged by graft, uniting the proximal metacarpal fragment to the phalanx. Function of long extensor and flexor tendons has been preserved.

Fig. 19-A

Fig. 19-B

Utilization of proximal and middle phalanges of functionless fifth digit for bone bridge between th carpus and proximal phalanx of ring finger. The transplanted joint flexes through a useful range of 45 degrees. Extension of ring finger gained through free tendon graft.

FIG. 10-A

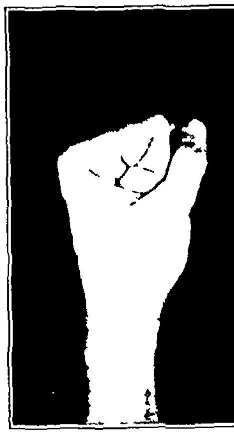

FIG. 10-B

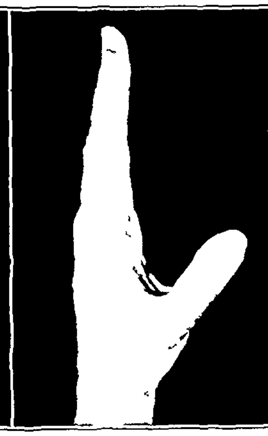

FIG. 10-C

FIG. 10-D

Fig. 10-A: Photograph showing compound fracture-dislocation of the first metacarpophalangeal joint, with loss of the flexor pollicis longus.

Figs. 10-B, 10-C, and 10-D: Thumb function following fusion of the metacarpophalangeal joint and free flexor-tendon graft. Fusion of the thumb metacarpophalangeal joint in flexion of from 20 to 30 degrees produces little disability.

FIG. 11

a: Metacarpal fracture, showing hyperextension deformity of the metacarpophalangeal joint and contracted collateral ligament. Dotted lines indicate preparation of the fragments to receive the graft.
b: Tibial graft has been shaped for insertion.
c: Illustrates various methods for bridging metacarpal defects. Note that, if the head and neck are present, the dowel is used; whereas, if only the head remains, a blunt end of the graft is impaled into the cancellous bone of the head. The distal metacarpal fragment or the proximal phalanx of the finger is adjusted so that, on flexion, the tip of the finger points to the tubercle of the navicular.

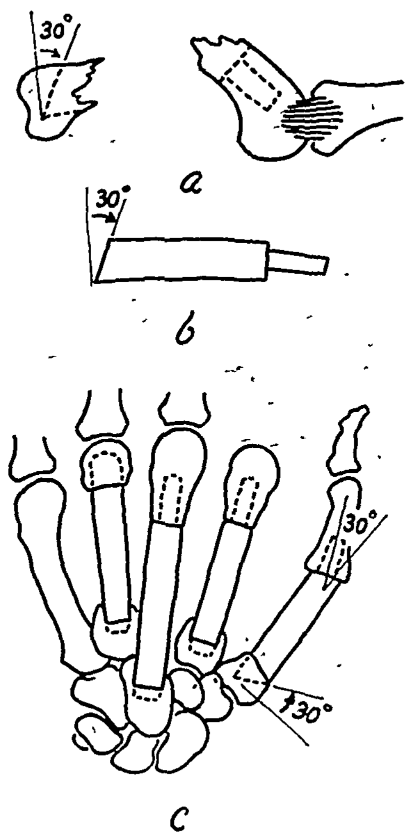

FIG. 11

The shortened finger with a stiff, hyperextended metacarpophalangeal joint (Figs. 6-A, 6-B, 6-C, *and* 6-D), which so frequently is a complication of a long-standing, badly comminuted metacarpal fracture[3], requires preliminary stabilization of the distal fragment with a bone graft, if useful function is to be restored. In cases in which joint flexion is not regained after bone-grafting, excision of the contracted collateral ligaments and lysis of the extensor tendon may be necessary (Figs. 7-A, 7-B, 7-C, 7-D, and 7-E). Excision of the collateral ligaments can be done at the time of grafting, if a sufficiently large distal metacarpal fragment is present. Once the metacarpal head has been stabilized, however, traction on the finger alone (Fig. 8) may restore flexion.

Disability resulting from loss of the first metacarpal is much greater than that occurring in the case of the other metacarpals. If the proximal portion of this metacarpal has been destroyed, the distal fragment can be fused to the carpus; and, if the thumb is placed and maintained in a functional position, a useful digit will result (Figs. 9-A, 9-B, 9-C, and 9-D). If the injury should involve the distal portion of this metacarpal with extension into the metacarpophalangeal joint, a fusion of the joint at approximately 30 degrees of flexion is recommended (Figs. 10-A, 10-B, 10-C, and 10-D).

Early immobilization of the injured hand in the position of function is of great value in the later procedures of reconstructive surgery. Following wound healing, every effort

PRIMARY ARTERIAL INJURY COMPLICATING EXTREMITY FRACTUR

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Experience with war wounds has taught surgeons the necessity of repairing damag arteries early, in order to re-establish and maintain circulation in a salvageable extremit Fractures and crushing injuries seen in civilian practice are also frequently complicat by severe damage to soft structures.

Injury to main arteries in certain areas means loss of the extremity, unless repair prompt and successful. If traumatized tissues have their blood supply decreased by vas spasm, shock, or direct injury to an artery, infection may develop in lacerations and com pound-fracture wounds, and tissue repair be decelerated. Chemotherapy is only effecti in direct proportion to the blood supply.

Shock can be combatted by blood transfusions and control of hemorrhage. Vaso spasm can be controlled by sympathetic novocain block or by one of the newer drugs such as tetra-ethyl-ammonium chloride, unless shock is present. Lacerated or trauma tized arteries with thrombi must be treated promptly by surgery, if a main vessel i involved; otherwise, gangrene will develop, and a potentially useful extremity will be lost

Accidents resulting from our present high-speed transportation and accelerate industry produce severe crushing injuries and compound fractures. Extensive damag to the soft tissues may result from the direct blow, as well as from wide displacement o the fragments of fractured bones.

It is axiomatic that preservation or re-establishment of the circulation to the extrem- ity must take precedence over any attempt to obtain a satisfactory reduction, fixation, or immobilization of the fractures. It, therefore, behooves the surgeon treating fractures to be constantly on the alert for any impairment of circulation distal to the fracture site; in such cases there is no greater emergency than a lacerated or thrombosed main vessel.

It is our purpose to present four typical cases of arterial injury associated with frac- tures, to discuss their diagnosis and treatment, and to emphasize the necessity for prompt attention in such instances. Case 4 is unusual in that anastomosis was obtained with a tantalum tube by non-suture technique.

Case 1, L. M. (No. 428887). This patient was admitted to the Emergency Department on October 7, 1944, suffering from a compound, comminuted fracture of the right femur, which occurred when she was struck by a truck. On admission, she complained of pain in the leg and numbness of the right foot. A tourniquet was in place. Roentgenograms showed a comminuted fracture at the junction of the middle and lower thirds of the right femur with considerable posterior displacement of the distal fragments (Fig. 1). There was no pulsation of the vessels of the foot. She was taken to the operating room and treated for shock by transfusion. Two compound fracture wounds were found on the posteromedial aspect of the thigh. These were cleaned, lavaged, and debrided. They were then connected by a small incision for investigation of the fracture site; this exposed the great vessels. One of the comminuted fragments was found to have rotated posteriorly and impinged directly on the femoral artery. At first glance, the artery appeared to be intact, but closer investigation revealed a bulbous swelling at the proximal portion of the wound, followed by a thinning out of the substance of the vessel and then, about one and a half inches distally, the normal thickness of the vessel could again be palpated. The fragments were manipulated out of the way, and a linear incision was made in the artery at the site of the injury. The adventitia and media were incised, and the intima was found to be completely ruptured and separated for a distance of about one and a half inches. Distally there was an extensive longitudinal laceration of the intima. Bulldog clamps were applied to the distal and proximal portions of the artery. The knee was flexed to relieve the tension of the vessel. A red thrombus was removed from the proximal end. The bulldog clamps were released, and the tourniquet was removed. Blood flowed freely. The clamps were then re-applied. The intima was sutured with fine artery silk, and the other layers

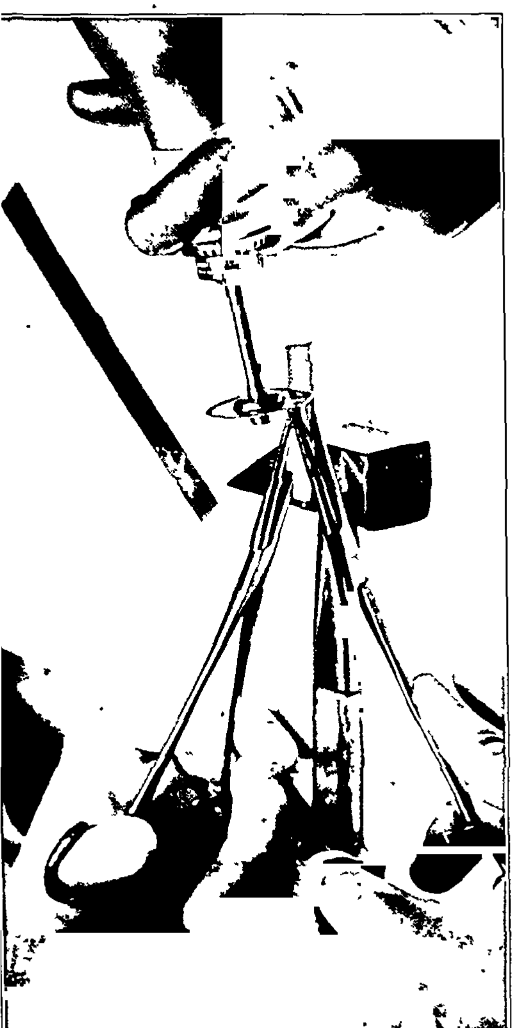


FIG. 12-E
Graft being cut to proper length, which is determined by measuring defect with traction on finger.

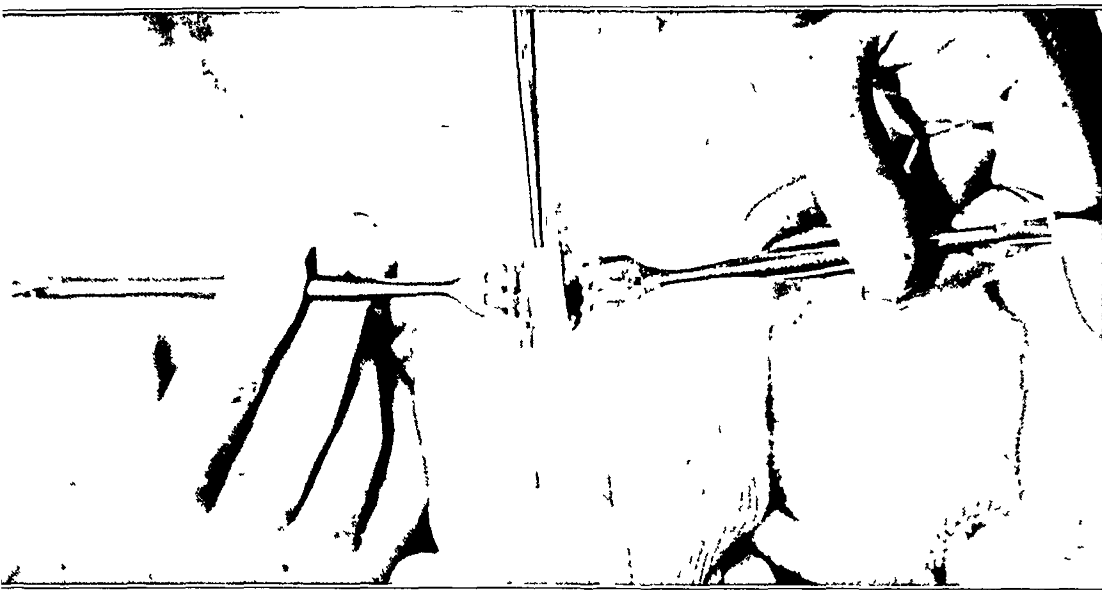


FIG. 12-F
Doweled end of graft being inserted into medullary canal of distal metacarpal fragment.

FIG. 12-G
Base of graft is being pressed into recess of proximal metacarpal fragment.

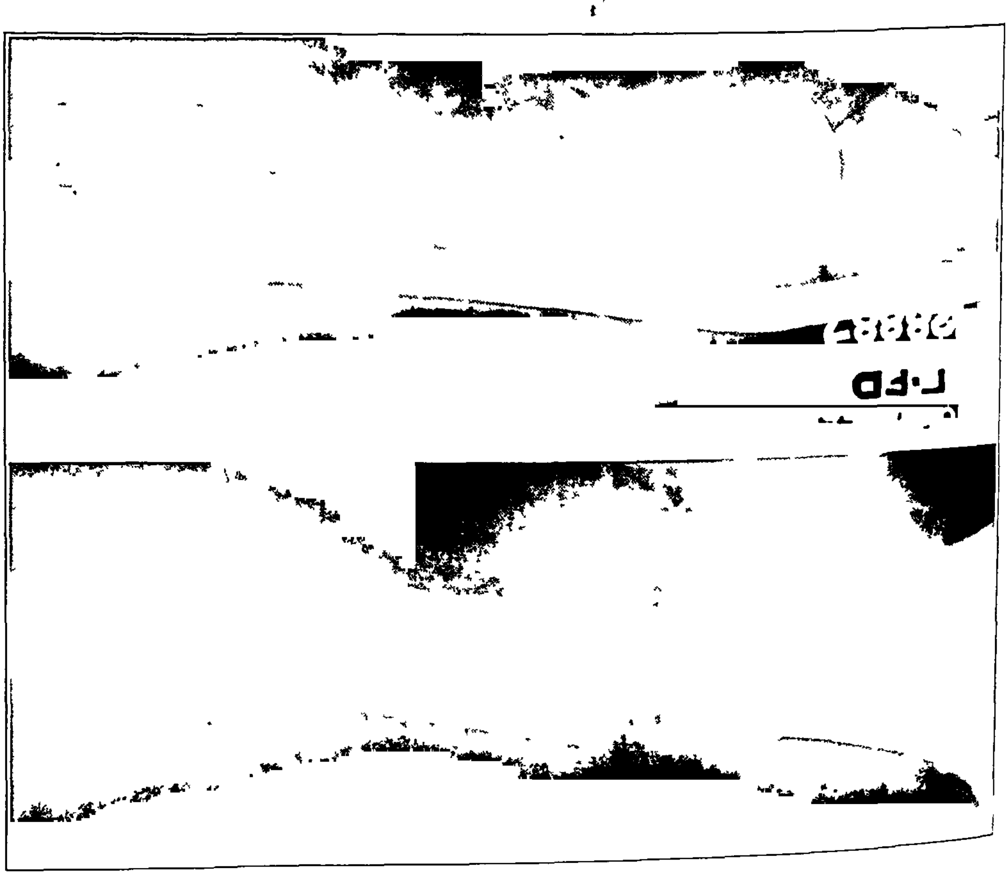


Fig. 1

Case 1. Compound, comminuted fracture of femur with extensive damage to femoral artery.

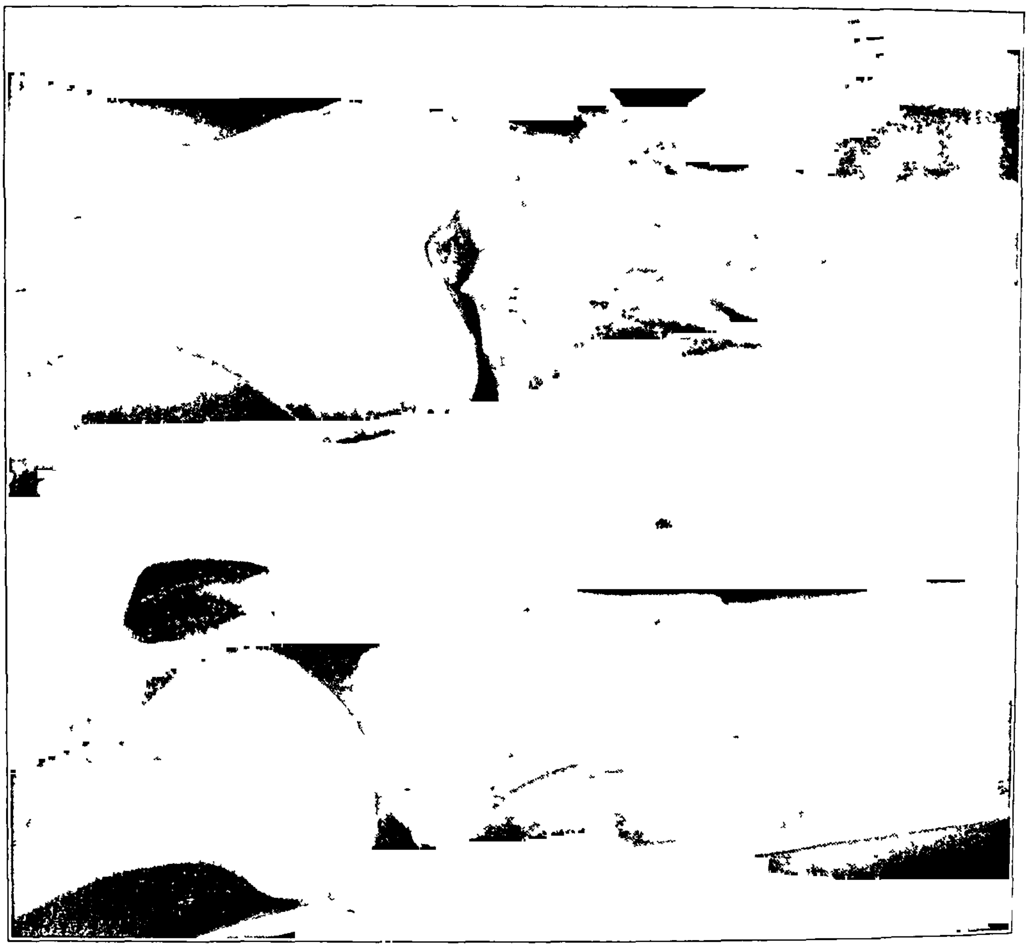


Fig. 2

Case 2. Comminuted fracture of tibia and fibula with injury to popliteal and tibial arteries.

Fig. 14-A

Fig. 14-B

Fig. 14-A: Shows destructive fracture of the fourth metacarpal.
Fig. 14-B: Photograph taken three months after operation shows union of graft to metacarpal fragments. Excellent function with full flexion at the metacarpophalangeal joint resulted.

Fig. 15-A

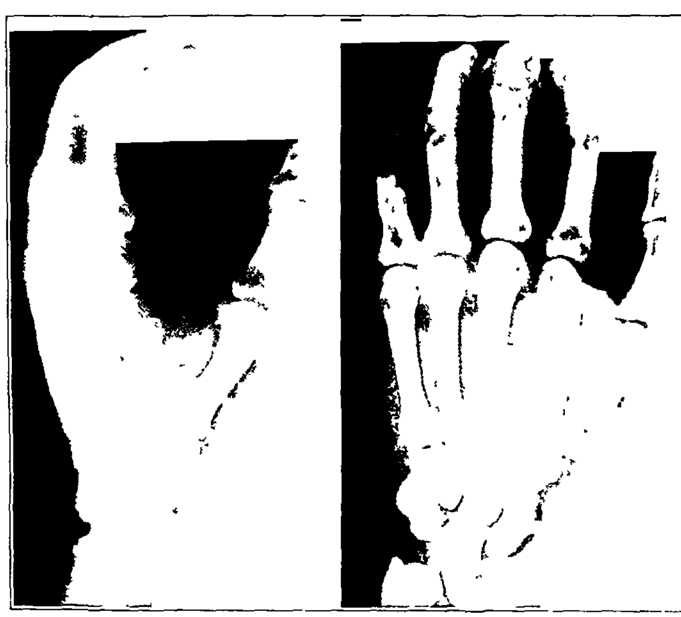


Fig. 15-B

Fig. 15-A: Malunited fracture of metacarpal of index finger, with volar angulation of distal fragment and internal rotation of finger.
Fig. 15-B: Showing correction by bone graft.

Fig 4-B

Case 4 Postoperative roentgenogram showing tantalum tube in place.

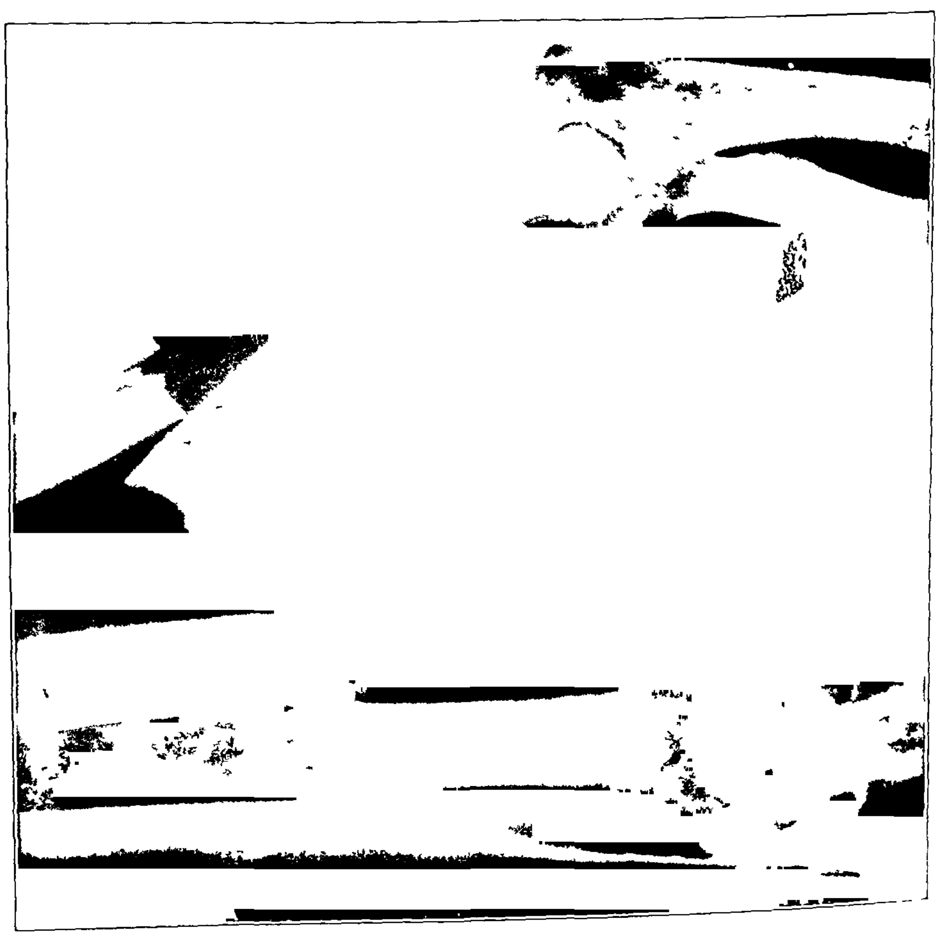
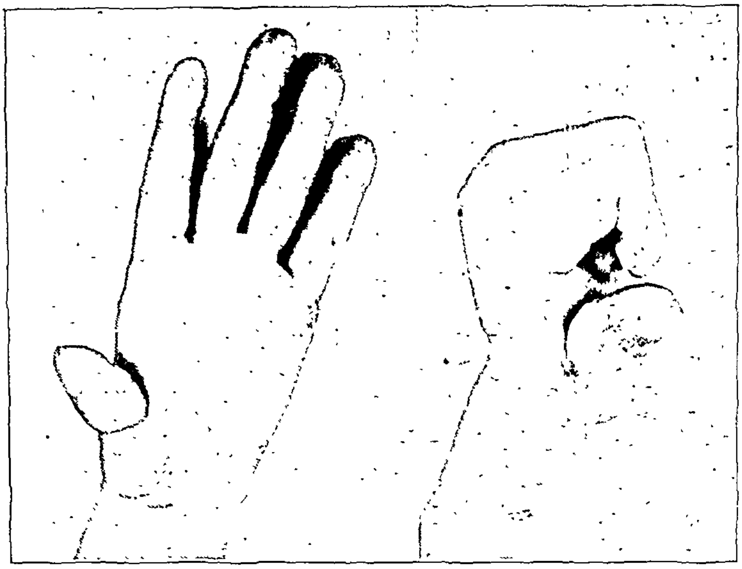


Fig 4-A

Case 4 Simple fracture of the humerus Brachial artery injured.



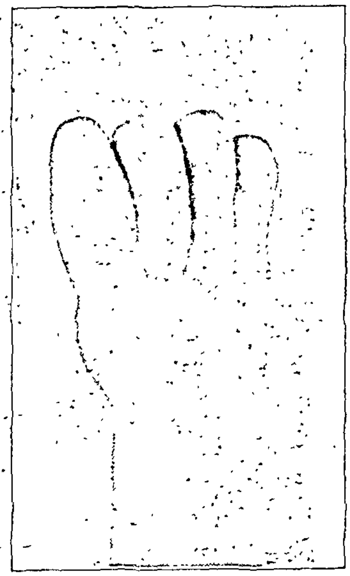


FIG. 17-C FIG. 17-D FIG. 17-E

FIG. 17-F FIG. 17-G FIG. 17-H

Fig. 17-A: Complete destruction of thumb metacarpal.
Fig. 17-B: Roentgenogram of iliac-bone graft between greater multangular and proximal phalanx, with thumb in functional position.
Figs. 17-C and 17-D: Preoperative photographs.
Figs. 17-E, 17-F, 17-G, and 17-H: After operation, the thumb can be opposed by the index and middle fingers.

ıd a graft, measuring at least one-half inch longer than the estimated defect, is taken om the upper end of the tibia. A dowel is fashioned at one end of the graft with the cirılar saw. The other end is cut obliquely at 30 degrees. The doweled end of the graft is ıserted into the medullary cavity of the distal fragment, and the proximal end of the raft is pressed into the metacarpal or carpal recess. Compression of the graft between ıe two fragments is sufficient to hold it in place at the base (Fig. 11, *c*). The periosteal eeve, if present, and the soft tissues are carefully closed over the graft with fine silk or otton sutures. The various steps in the operative procedure are illustrated in Figures 12-A ɔ 12-G, inclusive. Following operation, a plaster-of-Paris cast is applied, which extends ɔ the proximal interphalangeal joints, with the hand being maintained in the position of ınction. This cast is immediately split to facilitate postoperative decompression. On

reported both experimentally and clinically by Blakemore, Lord and Stefko. Further experimental work with tantalum tubes has been carried out by Lam of this institution.

The procedure used has been described by Blakemore and Lord [1] and the reader is referred to the original work for complete technical details. The pitfalls to be avoided have been discussed by the same group. They caution the surgeon to avoid the use of a tube that is too large for the artery. They also warn against a ligature which is too tight at the distal end of the tube and against injury or clot formation in the vein graft.

Tubes should be available in graduated sizes. In our opinion, nearby veins may be used at the time of the surgery, thus avoiding the necessity of "quick freezing" the tube and vein units, as suggested by other authors. It seems more reasonable to use homogenous tissue and avoid the possibility of tissue reaction.

The use of heparin has decreased markedly the danger of postoperative thrombosis. The fear of thrombosis must be balanced against the danger of hemorrhage and hematoma formation. Heparin is almost indispensable to the success of the procedure.

As far as we know, arteriography has not been done in this type of case. The value of the procedure described can be measured only by the clinical success.

DISCUSSION

These cases are presented and discussed individually to illustrate the damage that can be done to an important artery at the time a fracture occurs. The importance of early recognition of the impairment of circulation to an extremity cannot be overemphasized. Such a situation calls for emergency care.

Residents in charge of emergency admitting departments must ever be on the lookout for such cases, so that these patients will not be splinted or immobilized and sent to the ward. The next day will be too late, and amputation will be inevitable.

Case 1 is an example in which an amputation might have been avoided, if a metallic tube had been available and heparin could have been used.

Case 2 demonstrates the effect of a severe blow on an arterial tree with extensive damage, not by displaced bone fragments, but by the force of the blow itself[4].

Case 3 illustrates how easily the circulation can be impaired by localized compression of the artery with formation of a thrombus and development of vasospasm. This has been described by Cohen.

Case 4 is an example of a localized arterial injury, treated with a tantalum tube to bridge the defect. It is described in greater detail, because of the type of repair utilized.

We feel the use of heparin in these cases is of the greatest importance. In this may rest the success or failure of the operative procedure. Should hemorrhage occur—and the doctor must always watch for this—a tourniquet may be applied. Amputation may be necessary, but at least the extremity has been given a chance to re-establish circulation. Without heparin, failure of circulation is more likely, with possible amputation.

The surgery involved in arterial repair is tedious, time consuming, and extremely fatiguing for it calls for painstaking attention to details, and after the operation has been finished, there is still the fracture to treat. Regardless of the effort expended, there is a much better chance of obtaining an intact and useful extremity.

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about the twelfth day a new cast is applied (Fig. 13), immobilizing only the grafted metacarpal and the proximal phalanx. A period of two months is required before good union is present (Figs. 14-A, 14-B, 15-A, 15-B, 16-A, 16-B, 17-A to 17-H, 18-A, and 18-B).

Penicillin is given routinely for eight days after operation, because all of these patients have had compound fractures, either potentially infected or previously complicated by osteomyelitis.

To date, forty-four patients have had metacarpal grafting with a total of fifty-six individual grafts. As many as three grafts have been placed at one time. Individual grafts have been used for each metacarpal. Clinical union and callus formation, with loss of the sharp line of demarcation between the graft and the fragments, have resulted during the third month in all grafts except three (two small grafts were absorbed, and one failed to unite to an atrophic third metacarpal head which was angulated volarward). It has been possible in several cases to utilize bone from an amputated finger to restore a metacarpal (Figs. 19-A and 19-B).

CONCLUSIONS

In selected cases of metacarpal fractures with loss of bone substance, bone-grafting is a worth-while procedure for relieving pain at the fracture site and for restoring the normal architecture, strength, and function of the hand.

NOTE: The author wishes to acknowledge the kind suggestions made for the preparation of this paper by William J. Tobin, M.D.

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CHONDROITIN SULPHATE IN CARTILAGE

Origin

Most authors assume that the chondrocytes elaborate this substance[10], but direct evidence is still lacking. Hansen has scrutinized different theories, without settling the question. Clark and Clark were unable to decide whether the hyaline matrix was produced by the chondrocytes or by some alteration of the intercellular medium. The observation that the chondrocytes are surrounded by a large amount of chondroitin sulphate has thus far served as indirect proof of its elaboration by the chondrocytes; but, remarkably enough, no precursor has been demonstrated in the cell cytoplasm by histochemical or other methods. Thus, nothing is known of the ester-sulphate metabolism in cartilage. Additional data are needed badly, and will probably be supplied by using labeled sulphur. Some factors influencing the production of chondroitin sulphate will be mentioned in this paper.

Distribution

A small amount of ester sulphate can be demonstrated in the precartilaginous mesenchyme[19, 28]. In the embryo, the cartilage anlage becomes enveloped by a connective-tissue sheath, the perichondrium, which is supposed to serve as a "protecting" membrane. Inside this closed structure, growth and differentiation of cartilage proceed, and the specific matrix is developed. During the embryonic development, there is a low ratio between matrix and cells; this ratio increases during infancy, until the typical ratio in each type of cartilage is reached. No analytical data are available concerning the amount of chondroitin sulphate in embryonic cartilage but, judging from the metachromatic reaction the amount seems to be fairly high. It seems by no means impossible that the local percentage concentration of chondroitin sulphate in the intercellular medium could be nearly as high as in adult cartilage.

Chemical analyses have shown that each type of cartilage has a certain normal amount of chondroitin sulphate (Table I). Maximum amounts have been reported in the adult period of life[15, 36]. Additional details regarding articular cartilage are included in reviews by Hansen, Benninghoff, and Hirsch.

The validity of the percentages of chondroitin sulphate given in Table I is limited, because of several factors. The figures give no information as to the regional variations in content of ester sulphate, nor as to the local concentration of chondroitin sulphate in the intercellular substance. From a biological point of view, such data would be extremely valuable; and they may be obtained by using a technique for histochemical determination. These questions have, to some extent, been studied by earlier authors, but sufficient data are still lacking[42].

To illustrate the regional variations in ester-sulphate content, it may be mentioned that the surface zones of articular cartilage generally contain a smaller amount of metachromatic material than the perpendicular zone[3, 14, 17, 42]; a proper explanation for this observation is still lacking. On the other hand, many investigators have stated that the local concentration of chondroitin sulphate is maximum around the chondrocytes, and that the amount decreases farther off into the intercellular substance. Theories have been advanced for the interpretation of this fact, but final proof is lacking.

Chemical [15, 36] and histochemical investigations [42] would suggest a constant depletion of chondroitin sulphate with aging. This fact must be correlated with a number of different factors and simultaneous changes affecting cartilage during this period of life. From infancy to old age, a continuous decrease in the number of cells is found in articular cartilage[40]. At the same time, the content of calcium increases[15]. In addition, a continuous process of cell degeneration proceeds, accompanied by many changes,—such as calcification, pigmentation, amianthoid degeneration, and fibrous metaplasia of cartilage. The

were similarly approximated. The suture line held well when the bulldog clamps were removed. The pulsation extended well below the suture line. Because of the extensive nature of the compound wound, it was felt inadvisable to heparinize this patient. She was in moderate shock in spite of her transfusions. The wounds were, therefore, closed with chromic catgut. To control the fragments, Steinmann pins were inserted through the upper third of the tibia and the os calcis for traction. A Thomas splint was applied.

No arterial pulsation was ever obtained in the foot. The foot remained cold, and mummification set in within four days. Permission for amputation was denied until October 23, 1944, when a mid-thigh amputation was done. Convalescence was uneventful. The patient was discharged from the Hospital on November 11, 1944. She was followed in the Out-Patient Department until May 14, 1945, at which time she was walking with a prosthesis.

This case illustrates the problems of treatment before the advent of the metallic tube. A severe compound fracture was complicated by laceration of the main artery by a displaced bone fragment and extensive damage to the other soft structures. The femur was badly comminuted, and very active bleeding from the medullary cavity took place when the tourniquet was released. This hemorrhage, plus scattered minor bleeding, made the use of heparin seem inadvisable. Yet we are convinced that, by preventing postoperative thrombosis, heparin might have made the anastomosis successful.

Case 2, S. K. (No. 34878). This patient, having been struck by a motor car, was admitted on February 20, 1946, to the Emergency Department, with comminuted, intra-articular fractures of the upper third of the left tibia and fibula. The extremity had been struck from the rear by the car bumper. There was also a laceration of the scalp and cerebral concussion. The scalp laceration was sutured. The left leg, distal to the fracture site, rapidly became swollen. Extensive bleb formation took place. The pulsation of the dorsalis pedis and the posterior tibial arteries could not be felt. Motor and sensory paralysis existed below the fracture site.

Roentgenograms failed to show any displaced fragments which might have lacerated the nerves or vessels (Fig. 2). During an hour's observation, swelling of the leg increased in spite of elevation of the leg, and a mass, which seemed to pulsate, was noted in the popliteal space. It was, therefore, deemed advisable to explore the popliteal region for a lacerated artery.

A linear incision, about eight inches in length, was made in the popliteal region, with a tourniquet in place. The tibial nerve was encountered and was found to be hemorrhagic for a distance of several inches. The artery and vein were isolated and were followed between the heads of the gastrocnemius. The vessels were seen to pass into the torn soleus, and a large hematoma was found just beneath it. The vein was completely ruptured. The popliteal artery was isolated, and the posterior tibial artery was found torn at the bifurcation. Available Vitallium tubes were found to be too large for vessels of this size. It was impossible to suture the vessels, because of the type of laceration. The posterior tibial artery and vein were, therefore, ligated. The defect in the popliteal artery was sutured with fine artery silk. The tourniquet was then released and the suture line seemed to hold well. Two cubic centimeters of heparin was then injected into the artery, proximal and distal to the traumatized area. The vessel was seen to pulsate distal to the area of repair. Because of the severe oedema, the wound could not be closed. A vaselin dressing was applied, and the extremity was splinted.

After the patient was returned from the operating room, heparin was started. The toes soon became cyanotic, and the cyanosis increased the following day. A left lumbar sympathetic block was done without improvement in the circulation of the extremity. The next day the block was repeated, again without result. The leg became progressively gangrenous, and, on March 1, 1946, a mid-thigh amputation was done. Recovery was uneventful. The patient was discharged from the Hospital thirteen days later and was walking with a prosthesis when last seen on October 3, 1946.

Secondary thrombosis occurred in this case in spite of heparin and a sympathetic block. The arterial damage was too extensive to have been overcome, even if a metallic tube of the correct size had been available. It should be noted that, in this case, the soft-tissue damage was caused solely by the force of a crushing injury. The bone fragments were not appreciably displaced. Such injuries to arteries can occur in the absence of any fracture.

Case 3, J. H. (No. 66406). This patient was admitted to the Emergency Department on March 1 1945, after an industrial accident. Examination revealed a severe, compound, comminuted fracture f mid-portion of the left humerus (Fig. 3), complicated by paralysis of the ulnar nerve and absence pulsation at the wrist. The man was taken directly to the operating room, where the compour wound was carefully cleaned, lavaged, and debrided. Incision was then made over the medial

vial membrane and fluid, respectively. Accordingly, knowledge is scant as to the morphological changes in cartilage, due to derangement of nutrition. In this respect, Maximow and Bloom suggest that articular cartilage will become dedifferentiated when mechanical function has deteriorated, and this might also imply a disappearance of chondroitin sulphate. The so-called "dedifferentiation" of cartilage cultured *in vitro* is discussed in a later section.

METABOLISM OF CARTILAGE

The concept has been adopted that cartilage metabolism decreases gradually with old age, largely because of the gradual decrease in the number of cells. The rate of glycolysis was found to be proportional to the number of cells, but oxygen consumption decreased more rapidly, indicating a progressive cell degeneration with aging[40]. The glycolytic and oxidoreduction enzyme systems of cartilage were reviewed by Lutwak-Mann. Very little is known concerning the metabolism of fat and proteins in cartilage.

We are forced to assume a continuous exchange of chondroitin sulphate in normal cartilage, comprising some consumption and resupply, but the details have not been established. In all probability, the turnover of chondroitin sulphate will also become a part of the future research on sulphur and sulphate metabolism. Some changes taking place in the metabolism of cartilage have, however, been described in immature guinea pigs, which were subjected to undernourishment, thyroidectomy, and the administration of pituitary extracts[45, 46, 47]; but, unfortunately, the technique for the demonstration of chondroitin sulphate was imperfect, so that no conclusive statements could be made.

Rickets

In rickets, the hypertrophic epiphyseal cartilage cells present the usual staining reactions. Thus, there is probably no decrease in chondroitin-sulphate content, a suggestion supported by the analysis of Miyazaki. Pierce reported the same hydrogen-ion concentration in both healthy and rachitic epiphyseal cartilage. On the contrary, the simultaneous degeneration of matured cartilage cells on the diaphyseal side is known to be associated with a rapid disappearance of chondroitin sulphate[43], a process which corresponds to normal endochondral ossification.

Scurvy

It is generally assumed that the formation of the cartilaginous matrix is impaired in vitamin-C deficiency[21]. Using a defective metachromatic staining technique, Meyer[29] recently asserted that the production of chondroitin sulphate was prevented in scorbutic cartilage. Conclusive results concerning this are lacking, as is also a comparison with the content of alkaline phosphatase in scorbutic cartilage[6, 12].

Regarding the metabolism and possible turnover of chondroitin sulphate in articular cartilage, we should consider the possible role of the so-called "hyaluronic acid" and the corresponding enzyme system "hyaluronidase". The synovial fluid contains hyaluronic acid[34], which has a composition related to that of chondroitin sulphate[8]. Hyaluronic acid is hydrolyzed by hyaluronidase and, furthermore, this enzyme group also hydrolyzes both the isolated, partly depolymerized chondroitin sulphate[31, 38] and the native substance, according to Hirsch. Hyaluronidase has been obtained from many bacteria and, in large quantities, from testes[26, 34], but has not yet been demonstrated in synovial fluid. The results outlined in this paper may contribute to the future solution of many problems, particularly with regard to the genesis and metabolism of chondroitin sulphate in articular cartilage, under both normal and pathological conditions. In all probability, the enzyme will be demonstrated in synovial fluid; and this might serve as an explanation for the low content of chondroitin sulphate in the superficial part of articular cartilage. On the other hand, an increased content of hyaluronidase of bacterial origin would explain

FIG. 3

Severely comminuted fracture of left humerus with injury to brachial artery.

middle third of the arm. The basilic vein was identified and retracted, as were the median and ulnar nerves. Next, the brachial artery was isolated and found to be in severe spasm throughout the entire length of the incision. One of the comminuted bone fragments was rotated and impinged directly against the vessel. A bulbous thickening of the vessel was found at the site of injury, distal to which the artery appeared to be collapsed. The artery was incised at the site of the dilatation; and a red thrombus, one inch in length, was removed. The intima was slightly torn. Blood spurted through the incision in the vessel wall. A bulldog clamp was applied. Compression of the forearm forced blood from below through the incision. The vessel was closed with artery silk, and the incision in the skin was closed with fine chromic catgut. A Kirschner wire was then inserted in the olecranon process of the ulna. Traction was applied in a Thomas arm splint after the patient was returned to his bed. A faint radial pulse could be felt after the procedure was over. The patient was heparinized for three days. The radial pulse improved and was of normal intensity.

In two weeks, the Kirschner wire was removed, and the extremity was placed in a hanging arm cast. The patient was discharged from the Hospital on April 2, 1945. Healing of the fracture took place with a moderate degree of angulation. Paralysis of the ulnar nerve persisted.

The patient was readmitted to the Hospital six months after the injury for a neurolysis of the ulnar nerve and transposition of it to the antecubital region. He was discharged one week later and followed in the Out-Patient Department. When last seen, he showed good return of the sensory and motor functions of the ulnar nerve.

The suggestion may be advanced that the acid reaction favors some enzyme systems, while inactivating others. In another paper on this subject, to be published later, this question will be treated with regard to the action of alkaline phosphatase. However, the elucidation of this important question is hampered by the present defective knowledge of the native state of chondroitin-sulphuric acid and its protein linkages.

Molecular Structure

A recent report by Barcroft and his associates, on the diffusion rate of certain dyes in Wharton's jelly, is of especial interest. Their results favor the suggestion that this tissue might serve as a non-vascular conducting path for nutritional fluids and substances. Without presenting any experimental proof, Bacsich and Riddell have advanced the idea that this non-vascular pathway was effected by the ester sulphates present in Wharton's jelly. The corresponding suggestions should also be applicable to the cornea and cartilage. However that may be, it seems probable that the molecular structure in some way might favor diffusion; but conclusive evidence is needed.

Mechanical Function

According to Hirsch, chondroitin sulphate is partly responsible for the maintenance of cartilage elasticity. Patellar cartilage with a reduced content of this substance always exhibits impaired elasticity, "particularly a deterioration in its capacity to withstand loading". Hirsch, however, did not go further into the physicochemical interpretations of this observation.

Further suggestions might be advanced, but they would seem to be unjustified, because of the present very defective knowledge of the possible function of chondroitin sulphate.

DISCUSSION

This review is intended to emphasize that our views on cartilage have until now been largely morphological. Evidently, we have neglected the biological significance of chondroitin sulphate. By focusing our attention on this substance, and with the aid of the recent advances in glycoprotein chemistry, we should arrive at another and perhaps more biological opinion. We have good reason to assume that *chondroitin sulphate occupies the central position in cartilage biology*, and probably plays a very important role in the metabolism and function of cartilage. Most of our current problems concerning cartilage deal, or will in the near future be dealing, with the occurrence, distribution, and function of chondroitin sulphate. When we consider the physiopathology of cartilage, it seems still more urgent to get new information on the changes influencing this substance and on the physiological effect of such changes. It would be fruitful in a future approach to concentrate more interest on the role played by chondroitin sulphate.

NOTE: Two other articles on this subject, written by the same author, have been received and will appear in subsequent issues of *The Journal*.

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This arterial injury was one of simple compression and thrombus formation, without extensive damage to the vessel itself. Severe vasospasm was present. Removal of the thrombus, heparinization, and reduction of the fracture resulted in a satisfactory recovery in a case which might otherwise have come to amputation.

Case 4, E. H. (No. 468899). This patient was admitted on February 28, 1946, after slipping on an icy street and being struck by an automobile. She was seen in the Emergency Department about two hours after the injury, complaining bitterly of the pain and paraesthesia in the left hand, which had been present since the accident. Roentgenograms revealed a transverse fracture in the middle third of the left humerus (Fig. 4-A) and also fractures of the sixth, seventh, and eighth ribs. A compound-fracture wound was present on the posterior aspect of the arm, about three inches above the elbow. There was normal motor function in the hand and wrist. The sensory disturbance was generalized, and involved the entire hand, which was blanched and cold. No radial or ulnar pulse was obtainable. No extensive hemorrhage was noted at the fracture site.

Inasmuch as it was thought possible that one of the fragments might have compressed a vessel, the fracture was carefully reduced with fluoroscopic control. This procedure failed to improve the circulation of the hand. After a one-hour wait, a sympathetic block of the stellate ganglion was performed, which was successful as evidenced by the appearance of Horner's syndrome. This seemed to render the hand somewhat warmer, but it remained blanched and pulseless. After an interval of two hours, the circulation was still inadequate, and an exploration of the brachial artery was done.

Under pentothal-sodium anaesthesia, a ten-centimeter incision was made over the medial aspect of the upper arm at the posterior border of the biceps. There was considerable hemorrhage and evidence of trauma to the subcutaneous tissue in this region. The deep fascia had been lacerated along the medial border of the biceps, and a fragment of the fracture had extended anteriorly through the brachialis muscle and its fascia. The brachial artery was exposed for the length of the incision and isolated from the accompanying structures. An area of thrombosis, approximately one centimeter in length, was found in the artery in the mid-portion of the incision; a smaller thrombus was seen four centimeters proximal to the injury. There was evidence of spasm of the entire portion of the artery viewed. The median nerve was explored above and below the fracture site and found to be uninjured. The thrombosed region of the artery was isolated, and the surrounding tissues were packed out of the field of operation with moist gauze. Bulldog clamps were applied above and below the thrombus. A linear incision, one centimeter long, was then made over the area of thrombosis, and the clot was removed. The intimal lining of the artery was severely injured for a distance of approximately one-half centimeter on its posterior aspect. The wall of the artery was considerably thinned in this region. It was impossible to perform a direct anastomosis to eliminate the defect, and it seemed advisable to use a tantalum tube. A tube of proper diameter and length was obtained from C. R. Lam, M.D., who was using tantalum tubes in his experimental work in blood-vessel surgery on animals. The artery was transected at the site of the injury, and the injured portion of the vessel, about two centimeters in length, was excised. The smaller proximal clot was aspirated with a smooth, small cannula. The column of the artery, both proximal and distal to the injury, was heparinized. The tantalum tube was then prepared, according to the method described by Blakemore and his associates. A section of vein, of adequate diameter and length, was taken from the larger of the venae comitantes, which were in direct relation to the brachial artery. The vein was washed out immediately with heparinized saline, care being used not to injure the intima. It was threaded through the tube, and the ends were everted and secured with a fine ligature beyond the ridges in the tube. The tube was then inserted with the distal end of the vein section in the proximal end of the artery to eliminate danger of obstruction by the valves of the vein. This was easily done with very little stretching of the proximal end of the severed artery. The artery was pulled well onto the tube, and a silk ligature was placed tightly around the artery past the ridge of the tube. A fine ligature was likewise placed snugly, but not tightly, distal to the ridge. A similar procedure was carried out at the distal end, but with more difficulty, because of the smaller diameter of the artery. At this point, heparin was given intravenously, the procedure was completed, and the clamps were released. The artery was now seen to pulsate distal to the tube. The incision was closed in layers, and a posterior plaster mold was applied to the extremity for fixation.

The patient was heparinized, and the clotting time was maintained at five to six minutes. The patient was given penicillin for a period of eight days.

Immediately following the operation, the patient was in mild shock and the radial pulse could not be palpated. Two hours following the procedure, however, the hand had a normal temperature, and the pain had subsided. On the second day, palpation revealed a good radial pulse which remained strong. A hanging arm cast was applied eight days later and removed on the twenty-first postoperative day (Fig. 4-B). A good radial pulsation was present, which was watched for forty-eight hours. The patient was discharged from the Hospital on March 22, 1946. She was followed in the Out-Patient Department; satisfactory union and good circulation in the extremity developed.

As far as we can determine, this is the first case in which a tantalum tube has been used to bridge an arterial defect in the human. Vitallium tubes have been used and

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CARTILAGE AND CHONDROITIN SULPHATE

I. The Physiological Role of Chondroitin Sulphate in Cartilage *

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In spite of recent contributions regarding the composition, molecular structure, and protein reactions of chondroitin-sulphuric acid, our knowledge of the biological function of this substance in normal cartilage is still incomplete. Morphologists have hitherto avoided discussing this question; but the rapid advances in glycoprotein chemistry would seem to warrant an analysis of the subject. Consequently, more exact data are needed concerning the occurrence, genesis, and physiology of the native chondroitin sulphate. The complexity of the problems justifies a short review of the present conceptions of cartilage physiology with reference to chondroitin sulphate. The author is fully aware of the difficulties involved in presenting any interpretations of final importance.

QUALITIES OF CHONDROITIN SULPHATE

The chemical composition of the degraded chondroitin sulphate, or chondroitin-sulphuric acid, is well known [22, 23, 32, 33, 37, 44, 48]. The native substance presents a long-chain structure [4, 7, 30, 32, 33], has a very high molecular weight, and is slightly viscous in solution. The fibrous precipitates show little coherence. Chondroitin-sulphuric acid has a strongly acid reaction, due to both ester sulphate and carboxyl groups, which is of physiological interest. In cartilage, the substance is probably combined with protein by salt, or by other linkage [30]. On extraction with dilute alkali, the molecule is easily depolymerized[4], and consequently the relative viscosity is also influenced by slight variations in the pH of the solvent. Thus, the molecule presents a *sensitivity* which may be of fundamental importance in the interpretation of cartilage physiology.

METHODS OF DETERMINATION

The old *macrochemical* method involves extraction by weak alkali, and subsequent analysis of the degraded molecule [22, 23]. By the use of saline solutions for the extraction, more native preparations have recently been obtained [4, 7, 30], but the yield has usually been very low.

The metachromatic staining reaction, according to Lison, forms a qualitative test for the demonstration of ester sulphates of high molecular weight. Consequently, this staining reaction may be used for the *histochemical* assay of chondroitin sulphate, if no other ester sulphates are present in the same section. As far as we know, this happens to be the case in cartilage. If certain technical requirements are fulfilled when the sections are prepared (namely, uniform thickness and a standard staining technique), this method will also permit an approximate quantitative estimation of the content of ester sulphate [49, 50]. The metachromatic staining reaction has a very high degree of sensitivity [20]; and, with regard to the content of chondroitin sulphate in cartilage, it has given results which correspond very well with those obtained by the macrochemical method [17].

Unfortunately, no better methods are as yet available. It seems advisable to use both methods, since each has advantages of its own. The metachromatic reaction is, however, of prime importance for the exact localization of the ester sulphates under discussion.

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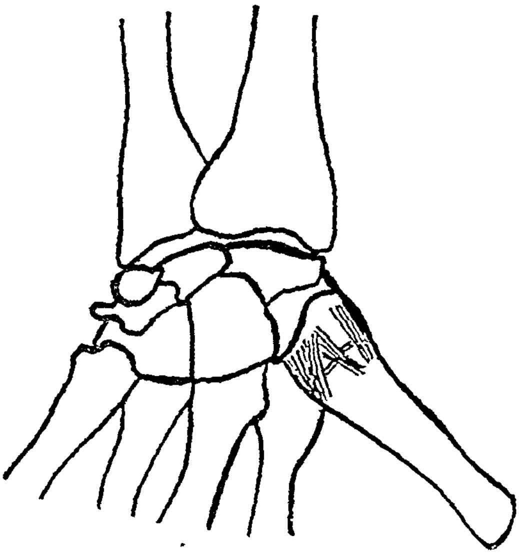

FIG. 1

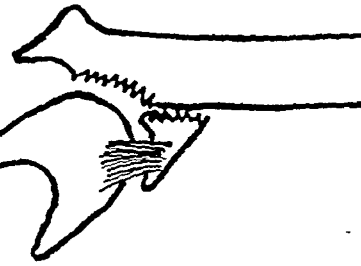

FIG. 2

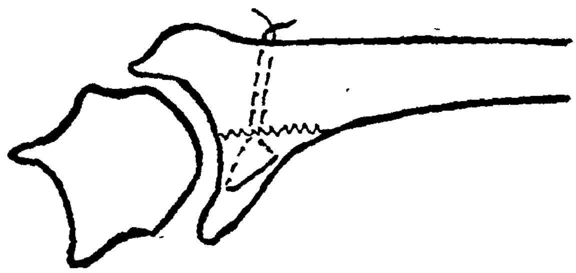

FIG. 3

Fig. 1: Diagram illustrating the capsular ligament of the first carpometacarpal joint on the volar aspect.
Fig. 2: Diagram illustrating a Bennett's fracture-dislocation.
Fig. 3: Diagram illustrating the method of maintaining reduction of the fracture with a mattress suture.

ments either remain separated, or are malunited in such a way that the mortise effect o the base of the first metacarpal is lost. The smaller fragment usually becomes united dis tally to the normal position; thus the palmar portion of the concavity, fitting over the greater multangular, and consequently the buttress effect, are lost. Malunion had occurred in all of the last three patients whom the author operated upon; and in one other case non-union of the smaller fragment was present. Traumatic arthritis of the carpometacarpal joint is also present in varying degree.

SYMPTOMS

The symptoms in all cases were similar. They consisted of weakness of grip, pain with use of the thumb, swelling of the carpometacarpal joint, and a dorsal prominence of the proximal end of the first metacarpal. In all patients these complaints had existed since the time of the original injury, and they were proportional to the amount of use of the hand. The severity of the symptoms also varied; it was noticed that patients with nervous temperaments complained more, as did those whose occupations necessitated greater use of the hand. All of the patients were willing to submit to an operation in order to improve the result.

TREATMENT

To repair the unreduced fracture physiologically, it is necessary to restore the ulnar portion of the saddle of the first metacarpal to its normal position, and thus restore the concavity. Following union, the dislocation cannot recur, as the previously inactive capsule begins to function. Bunnell recognized the necessity for such a repair, and was successful in using stainless-steel pins to hold the fragments together after open reduction. In the operation to be described, a mattress suture is utilized to hold the fragments together after they have been reduced.

OPERATION

After a tourniquet has been applied, a linear incision, one and one-half inches long, is made over the dorsum of the base of the first metacarpal and to the volar side of the extensor pollicis longus tendon. The incision is carried down to the bone, and the opponens

TABLE I

THE PERCENTAGE OF CHONDROITIN SULPHATE IN DIFFERENT TYPES OF CARTILAGE

Species	Age or Body Weight	Origin	Type of Cartilage	Amount of Chondroitin Sulphate in Dried Cartilage (*Per Cent.*)	Bibliographic Reference
Man	Young	Nasal septum	Hyaline	39–40	Miyazaki
Man	Middle aged	Nasal septum	Hyaline	26–33	Miyazaki
Pig		Nasal septum	Hyaline	41	Winter
Horse, ox, and pig		Nasal septum	Hyaline	37–38	Miyazaki
Horse and ox		Trachea	Hyaline	36–37	Miyazaki
Pig		Cricoid cartilage	Hyaline	38	Miyazaki
Man	35 years	Costal cartilage	Hyaline	11.4	Hass
Man	47 years	Costal cartilage	Hyaline	8.5	Hass
Man	60 years	Costal cartilage	Hyaline	6.9	Hass
Man	66 years	Costal cartilage	Hyaline	4.8	Hass
Rabbit	500–700 grams	Costal cartilage	Hyaline	37–38	Miyazaki
Rabbit	1,000–1,200 grams	Costal cartilage	Hyaline	29–31	Miyazaki
Rabbit	About 2,000 grams	Costal cartilage	Hyaline	23–24	Miyazaki
Man	40–48 years	Patella	Hyaline	19–25	Hirsch
Ox and rabbit		Knee joint	Fibrocartilage	15	Miyazaki
Horse, ox, and pig		External ear	Elastic	27–28	Miyazaki

possible effects of loss of mechanical function should not be overlooked, this loss being able to affect both the metabolism and the degree of differentiation of cartilage. Evidently, there is as yet no simple interpretation to explain the gradual loss of chondroitin sulphate. Hass has suggested that the production of chondroitin sulphate by the chondrocytes diminishes with aging, but the explanation may be much more complicated.

WATER CONTENT OF CARTILAGE

The intercellular matrix of normal cartilage constitutes a gel, containing about 70 per cent. water. The water content is dependent upon the actual chemical constitution of the chondroitin sulphate, and of the proteins and other electrolytes present. Changes in the composition and relative amounts of these substances result in changes of the water content. Thus, the content of water is a secondary phenomenon, and may be regarded as an indicator of alterations in the composition of the components of the gel. Therefore, the isolated study of the water content is of minor interest and is, moreover, very difficult to explain in detail.

NUTRITION OF CARTILAGE

It is generally agreed that cartilage, being largely devoid of vessels, gets the nutritive fluid by diffusion from the blood vessels of the perichondrium. This means that the fluid must pass through the interstitial substance to reach the chondrocytes[13, 28]. It is well known that injected dyestuffs are absorbed quickly by the cartilaginous matrix[28, 42]. With articular cartilage, we face more complicated conditions,—namely, nutritive exchange by percolation from the underlying bone, by diffusion through the synovial fluid, or perhaps in both ways[13]. As yet, we have no definite knowledge of the governing factors of this suggested diffusion mechanism. The physicochemical side of this mechanism is particularly obscure.

Thus, we do not know how the diffusion process is effected; we know only that it works in healthy cartilage. It may be postulated that such nutritional conditions render cartilage susceptible to alterations of the perichondrial connective tissue and of the syno-

RESULTS

Three consecutive cases were treated by the technique described, and the results were excellent in all. There was no pain, and the strength of the grip approached normal. The final roentgenograms showed that the smaller fragment was in a more normal position and that the mortise had been restored. Two of the three patients were seen periodically in the Out-Patient Clinic for several months and the results remained good, the patients being free of symptoms and able to perform their full duties. The third patient was seen for some weeks after operation, and the result was good when he was last seen. The roentgenograms of a typical case, before and after operative repair, are shown in Figures 4-A and 4-B.

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PAINFUL INTERDIGITAL CLAVUS (SOFT CORN)

TREATMENT BY SKIN-PLASTIC OPERATION

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Painful interdigital clavus and its etiology are well known. The conventional operation for the relief of this condition usually consists of a partial resection of the fourth metatarsophalangeal joint. This procedure appears to be a rather radical method of treatment for such a minor lesion.

Basically, the principle of the conventional operation is the removal of the normal underlying bone impinging upon the skin. The same effect can be attained more logically, however, by removing the overlying pathological skin of the affected toe and, by a simple

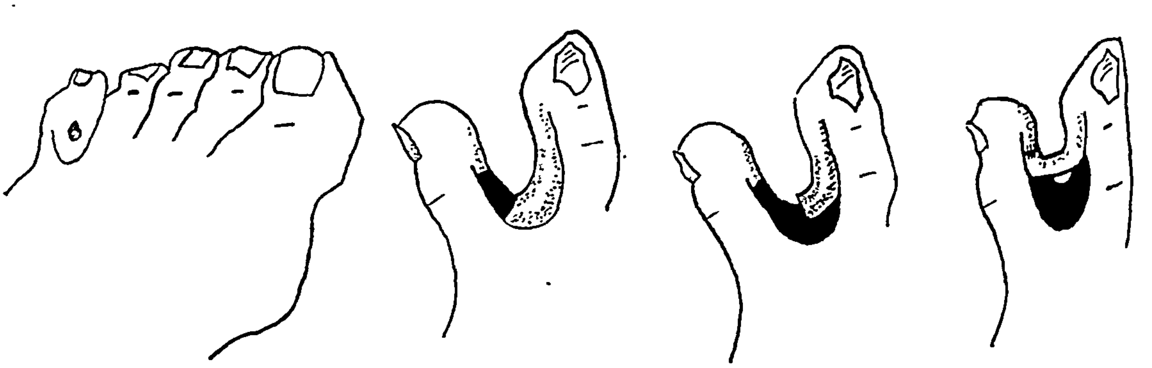

FIG. 1 FIG. 2 FIG. 3 FIG. 4

Fig. 1: Relation of soft corn to foot.
Fig. 2: Fourth and fifth toes spread apart, showing interdigital area. The soft corn has been excised: bare area is in black. Lines of incision shown for dorsum only.
Fig. 3: Medial skin flap being mobilized.
Fig. 4: Flap has been advanced and sutured. Defect left in black.

the rapid destruction of chondroitin sulphate, and possibly also that of cartilage, which occurs in some types of arthritis.

REGENERATION OF CARTILAGE

In adult cartilage, mitosis probably never occurs. The new formation is brought about by metaplasia of loose connective tissue, according to Maximow and Bloom. The slow development of cartilage cells from perichondrial cells and fibroblasts was studied by Clark and Clark, using the transparent chamber technique. From the standpoint of functional pathology, the metaplastic formation of new cartilage is an extremely slow process, extending over several months.

CULTIVATION OF CARTILAGE *IN VITRO*

Cultivation of small fragments of cartilage usually results in a subsequent dedifferentiation to a fibroblast-like cell type, and a rapid loss of chondroitin sulphate. On the contrary, cultivation of the whole cartilaginous anlage with the enveloping perichondrium *permits a slow growth of cartilage containing chondroitin sulphate* [5, 11, 16, 27, 35, 41]. *In this* way, the differentiation and growth of cartilage, the new formation of cartilage from mesenchyme and perichondrium, and to some extent the intramembranous and endochondral ossification have been studied *in vitro*.

Roulet cultivated simultaneously fragments of epiphyseal cartilage which were devoid of perichondrium, and rapidly growing fibroblasts; and he observed that, when they came into contact with each other, the cartilage matrix lost its metachromatic and basophilic staining reactions, and became acidophilic. The loss of ester sulphate was accompanied by degeneration of the chondrocytes, and after some time the fibroblasts digested the cartilage plate. A digestion process took place, apparently characterized by an early disintegration of the chondroitin sulphate. Roulet assumed, in conformity with Weidenreich, that some freely diffusible enzyme, liberated by the fibroblasts, was responsible for this. This experiment is of considerable interest, and would appear to be useful in explaining some processes in functional pathology. However, serious objections can be raised to this interpretation.

The observations of Roulet lose in value when the slightly alkaline reaction of the culture media and the sensitivity of the chondroitin-sulphate molecule [4] are considered. This applies also to most of the other experiments in cultivation of cartilage fragments which are devoid of perichondrium. Apparently, the usual culture media are unsuitable for the specialized nutritional requirements of cartilage. Nature itself sometimes starts cartilage cultures with more success,—namely, in the shape of intra-articular loose bodies, which show normal cartilage with a normal content of chondroitin sulphate. Obviously, the nutritional conditions in the synovial fluid are sufficient for both growth and maintenance of cartilage for many years [13].

THE FUNCTION OF CHONDROITIN SULPHATE

The aspects of cartilage physiology, mentioned previously, accentuate the necessity for analyzing the different qualities of chondroitin sulphate, in order to reach an opinion as to the functional significance of this substance in healthy cartilage. Obviously, the healthy state of hyaline cartilage must in some way be associated with a high content of chondroitin sulphate in its intercellular matrix. It is tempting to speculate that very specialized tissues (such as cartilage, the cornea, and the connective tissue of the umbilical cord), containing large amounts of glycoproteins, might have some qualities in common, which could give a hint as to the function of the glycoproteins.

Acidity

The significance of the strongly acid reaction of chondroitin-sulphuric acid is obscure.

OBSERVATIONS ON OBSCURE MECHANISMS OF NERVE-ROOT COMPRESSION WITH A DIAGNOSTIC TAP TEST

Report of Two Cases

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From the New Jersey Orthopaedic Hospital, Orange

In the study of the surgical relief of sciatic pain associated with backache, the authors have recently encountered an unusual mechanism of nerve-root compression, and have discovered a test of foraminal-root pressure, for use during an operation.

The unusual mechanism found was the compression of a nerve root against the superior pedicle and articular process in the foramen, by the disc bulging out below or distal to the root. A contraction of the gluteal and thigh muscles upon tapping the overlying facet proved to be the result of compression of the nerve root in the foramen.

Case 1. J. F. C., a machinist, aged forty-two, was admitted on December 28, 1945, complaining of severe pain in the lower part of the back and in the right buttock, thigh, and leg. He stated that he had injured himself five days before, while pushing a tool machine. Examination showed that he had an acute low-back affection with a loss of the ankle jerk on the right side.

At operation the fifth, fourth, and third intervertebral discs were explored. The only pathological change noted was that in the fourth disc, underneath the fifth root, there seemed to be an area of degeneration. A window was cut in the fourth disc at this point, and a piece of somewhat hard and degenerated material was removed with a pituitary forceps. Preparations were then made to perform a low-back chip fusion, and a rasp was hammered into the articulation joining the fourth and fifth vertebrae on the right side. A muscular contraction of the right buttock and posterior thigh muscles was observed. A complete foraminotomy [2] was then performed between the fourth and fifth vertebrae, with a wide opening of the intervertebral foramen. The response to tapping disappeared completely. It was observed that the disc bulged out into the foramen where it curved around to the lateral border of the spinal column. The protruding disc was shaved off with a scalpel, and the fusion was carried out between the fourth and fifth lumbar vertebrae.

This patient was discharged from the Hospital on the fifteenth postoperative day. He returned to work in April, three months following operation, and was last examined on May 3, 1946.

This case presented interesting features. The bulge of the fourth lumbar disc at its lateral border was not discovered until a complete foraminotomy had been performed, and only after this procedure did the contractions of the gluteal and thigh muscles, in response to tapping on the articulation, cease.

The authors are convinced that they would not have relieved the compressing mechanism which was producing the sciatic pain unless the observation of the muscle reaction to the tap on the articular process had given the clue to the presence of pathological changes in the underlying foramen.

Case 2. G. D., an ex-serviceman, aged twenty-one, who was admitted to the Hospital March 11, 1946, complained of severe pain in the lower part of the back with radiation of the pain down the posterior aspect of the right lower extremity. This discomfort had started insidiously about a year and a half previous to his admission, while he was a member of the Armed Forces. Physical examination showed limitation of back motion in all directions, positive straight-leg raising tests on both sides, and a diminished ankle jerk on the right side.

The patient was operated upon March 20, 1946. The fourth and fifth discs were explored, and, as is commonly found in young individuals, both discs were bulging. The fifth disc, however, had a very prominent posterior bulge. On the right side, a window was cut in the annulus beneath the first sacral root, and some disc material was removed, which, as is usually found in the young, was not degenerated. Preparations for a lumbosacral fusion were then started, and a rasp was driven into the lumbosacral articulation on the right side. There was a violent contraction of the left or opposite buttock and thigh muscles. The fifth disc on the left side was then explored. A window was cut in it, and disc material was removed from beneath the first sacral nerve root, but tapping still caused the muscles to contract. A complete laminectomy was performed on that side, and the foramen was visualized, but still the contraction on tapping persisted. It then became

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XANTHOMA OF THE ACHILLES TENDON *

BY MORRIS S. FRIEDMAN, M.D., CHICAGO, ILLINOIS

Xanthomatous tumors of the tendon sheaths are not uncommon, but only a few cases have been reported in the literature in which the tumor involved the Achilles tendon. Two cases of bilateral xanthomata of the Achilles tendon are recorded here, in both of which the tumors were among the largest of this type so far reported. One patient had multiple xanthomatous lesions on the hands and feet, in addition to those of the Achilles tendon. The second patient had isolated tumors of both heel cords.

CASE REPORTS

CASE 1. A white woman, forty-five years of age, was admitted to the Illinois Research Hospital† in April 1938, complaining of pain in the fingers and painful swelling of both heel cords. Ten years previously her attention had first been called to a small growth in the lower part of each Achilles tendon. These masses gradually enlarged and became painful. About three years before admission, a small painful tumor appeared on the left big toe; and subsequently several small tumor masses gradually appeared on the fingers of both hands. The past history and the family history were non-contributory.

Physical examination showed the patient to be a moderately obese, middle-aged white woman. Several small yellow plaques were present on both lower eyelids. On the extensor surfaces of the fingers of both hands were multiple small, hard, yellowish-brown tumors, which varied in size from 0.5 by 1 centimeter to 1.5 by 3 centimeters. Somewhat larger tumors were present on the extensor surfaces of both big toes and over both patellar tendons. Both Achilles tendons were enlarged about three to four times the normal size. The tendons felt hard and nodular, and were somewhat tender. The motion in the ankle joints was unrestricted.

The blood count and urine were normal. The blood-chemistry findings were as follows: sugar 118 milligrams, cholesterol 620 milligrams, and uric acid 4.5 milligrams per 100 cubic centimeters. The Wassermann reaction of the blood was negative.

On April 20, 1938, both Achilles tendons were explored. Each tendon was found to be infiltrated by a yellowish, hard, nodular mass, extending from the musculotendinous junction to the calcaneus. The greater part of this mass was resected in both legs. After the operation, the wounds healed *per primam.* The pain in the fingers was relieved by a few treatments with deep roentgen rays.

Microscopic examination of the tumor tissue disclosed collections of polyhedral cells, with abundant pale vesicular foamy cytoplasm and small irregularly shaped nuclei. The stroma consisted of oval stroma cells, with slightly granular cytoplasm and oval nuclei. Numerous vesicular lipoid-filled spaces were scattered throughout the tissues. The blood vessels were abundant. A few giant cells were found near areas of hemorrhage. The tumor was surrounded by a well-defined fibrous capsule, extending from which numerous fibrous septa subdivided the tumor into lobules. The microscopic diagnosis was xanthomata.

During the next four years, ten tumors of varying sizes were removed from the fingers, toes, and elbows. The largest of these, taken from the right triceps tendon, was the size of a hen's egg. The tumors were excised because they were causing pain. The microscopic picture of these lesions was identical with that just described. The blood cholesterol varied from 384 to 800 milligrams per 100 cubic centimeters.

Late in 1942, the patient again complained of pain and enlargement of both heel cords. In February 1943, the Achilles tendons were explored. Again the tendons were found to be diffusely infiltrated by a yellowish nodular mass, extremely fibrotic for the most part, except for a few areas of caseous softening. The greater part of the tendon was resected, leaving only a thin strip of tendon. The wounds broke down repeatedly and healed very slowly. The plantar-flexion power, weak at first, gradually increased as the resected tendons were replaced by thick scar tissue, and as the posterior tibial muscles and peronaei became increasingly stronger plantar flexors.

When the patient was last seen, in January 1945, she had no pain in her legs. The wounds were healed. A thick fibrous cord was palpable at the site of each Achilles tendon. There was a mild bilateral pes cavus deformity. The ankles could be dorsiflexed to 100 degrees. Plantar flexion was strong enough to enable her to stand on her tiptoes. Her gait was normal.

CASE 2. A white woman, thirty-seven years old, was admitted to the Cook County Hospital on December 6, 1943, because of progressive enlargement of both heel cords. Nine years before admission, she had first noticed a small, hard swelling over the lower part of each Achilles tendon. These masses gradually increased in size, until they extended as high as the middle third of the leg. The patient did not complain of pain and

* Read before the Chicago Orthopaedic Society, February 8, 1946.
† Service of Fred W. Hark, M.D.

AN OPERATION FOR OLD UNREDUCED BENNETT'S FRACTURE

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The old unreduced Bennett's fracture is frequently a very disabling condition, because of the deformity present and the resulting traumatic arthritis. It is characterized by weakness of the grip, pain upon motion, and a prominent carpometacarpal joint, caused by swelling and the dorsal metacarpal dislocation. In the author's experience, all the unreduced Bennett's fractures produced symptoms, the severity of which depended upon the patient's occupation and mental state. Since the unreduced fracture-dislocation is accompanied by traumatic arthritis, the symptoms are unlikely to improve greatly until the faulty mechanics have been corrected by a surgical reconstruction. The perfect restoration must be a physiological one, and must return the finger to normal anatomically. A successful technique, which meets these requirements and which has resulted in strong and painless hands, is presented.

ANATOMY [4]

The base of the first metacarpal articulates with the greater multangular and is saddle-shaped, fitting over the multangular. The metacarpal is held in place chiefly by the capsular ligament, which is stronger in certain places because of thickened portions or bands. Three of these bands are located on the volar surface, connecting the greater multangular and the first metacarpal, the largest of them being inserted into the palmar portion of the saddle of the metacarpal (Fig. 1). It is this ligament, whose chief function is to prevent a radial dislocation of the metacarpal, which becomes inactive in a Bennett's fracture, because the fracture occurs distally to the ligament's insertion into the process (Fig. 2).

The only muscles which are inserted into the base of the first metacarpal, and which therefore might influence the dislocation of the base in a Bennett's fracture, are three: the flexor pollicis brevis, the abductor pollicis longus, and the opponens pollicis. Only the proximal fibers of the flexor pollicis brevis are inserted near the base; the larger portion of the muscle has its insertion distally into the first metacarpal. Hence its effect upon the base during a dislocation would be minimum, as its chief actions are to flex, abduct, and rotate inward the metacarpal of the thumb; flex the first phalanx; and extend the second phalanx.

The opponens pollicis has its insertion along the whole lateral border of the volar surface of the shaft and head of the first metacarpal; and its main action is to flex, abduct, and rotate inward the first metacarpal.

The abductor pollicis longus is inserted into the radial side of the base of the first metacarpal. Its actions are to carry the first metacarpal radialward and forward, and at the height of its contraction it flexes the hand at the wrist. It is also a weak supinator of the forearm.

It is thus seen that none of the only three muscles which are inserted into the base of the first metacarpal are very effective in preventing a radial dislocation of the base; and one of them, the abductor pollicis longus, tends to assist such a dislocation. The only effective control of such a dislocation, therefore, is the radially placed thickened band of the ligamentous capsule; when this has been made inactive by fracture, dislocation occurs, being assisted by the abductor pollicis longus.

PATHOLOGY

In a fresh Bennett's fracture [1], the palmar portion of the base of the first metacarpal is broken off; an outward dislocation of the base occurs; and there is some degree of tearing of the carpometacarpal ligamentous capsule (Fig. 2). In the old case, the two bone frag-

ported a similar lesion on a finger. These early writers called the lesions myelomata or sarcomata. Heurtaux, in 1891, was the first to differentiate these lesions from sarcomata. Tourneux, in 1913, collected from the literature ninety-three cases of tendon-sheath tumors, which he called sarcomata of the tendons sheaths. Only eight of these tumors were on the lower extremities, and none was in connection with the tendo calcaneus. Harbitz classified these growths as real tumors, probably sarcomata of comparatively benign nature. All the later writers, however, agree that the lesions are benign.

Only a few cases of xanthoma of the Achilles tendon have been recorded. Ollerenshaw described an eighteen-year-old girl with xanthomata of both Achilles tendons and xanthelasma on the right arm. He resected the tendons, and he reported no recurrence three years after the operation. McWhorter and Weeks described a negro, thirty-nine years of age, with a blood cholesterol of 600 milligrams, generalized xanthomatous lesions, and involvement of both Achilles tendons. They excised the tendons and reconstructed them with fascia lata. Young and Harris reported a woman of twenty-one with very marked enlargement of both Achilles tendons, which were diffusely infiltrated by xanthomata. These authors also excised both tendons and reconstructed them with strips of fascia lata. Galloway, Broders, and Ghormley, in 1940, reported seventy patients who had a total of eighty-eight xanthomata of the tendon sheaths and synovial membrane. Of the sixty-five patients with tendon-sheath tumors, only four, all females, had lesions in the tendo calcaneus; and in three, the lesions were bilateral. All four patients had xanthomata at sites other than the Achilles tendon,—mainly on the hands and feet.

INCIDENCE

Galloway, Broders, and Ghormley, in an excellent review of the subject, found 274 cases of xanthomata of the tendon sheaths reported in the literature from 1860 to 1938; to these they added sixty-five cases of their own. Jaffe, Lichtenstein, and Sutro, in 1941, reported fifty-five additional cases. The sex and age incidence and the location of these lesions have been similar in the approximately 400 cases thus far reported. About 60 per cent. of the patients were females, and 40 per cent. were males. Tumors of the Achilles tendon, few as there were, were almost entirely confined to females. The usual age was the third or fourth decade, the average being forty years. The youngest patient reported was five years old; the oldest, eighty-two years.

LOCATION

The lesions were two or three times as common in the upper as in the lower extremity. The majority of the tumors were located in the tendons of the wrist and fingers. About 60 per cent. of the tumors in the wrist and fingers were found on the flexor surface, and 40 per cent. on the extensor surface. In the lower extremity, most of the lesions were about the foot and ankle, mainly on the extensor surface. Most of the patients had only a single lesion, but in a few there were multiple tumors in one or more tendon sheaths.

SIZE

There was a wide range in the size of these tumors. Among the largest lesions described were those involving the Achilles tendon. The tumors described by Young and Harris measured twenty-two centimeters on the left leg and fourteen centimeters on the right leg. One of the most extensive lesions found was that reported by Cristol and Gill. Their patient, a man, aged forty-six years, had such an extensive involvement of all the tendons and soft tissues of the lower third of the leg and foot that amputation was necessary. The smallest tumors were found on the fingers, some of these being 0.5 centimeter in diameter. The size of the average tumor in the upper extremity was one by two centimeters; that in the lower extremity was four by five centimeters. In general, the more peripheral the location of the lesion, the smaller was its si--

FIG. 4-A

FIG. 4-B

Fig. 4-A: Preoperative roentgenogram of unreduced Bennett's fracture, illustrating the dislocation and malunion.

Fig. 4-B: Roentgenogram taken after operation shows reduction of the fracture-dislocation and restoration of the metacarpal mortise.

pollicis and flexor pollicis brevis are then stripped off, so that the carpometacarpal joint is exposed on the palmar side. Care must now be exercised in exposing the fracture site, as that part of the capsule attached to the smaller fragment must not be cut. A small linear incision is made into the capsule over the fracture site, where it is usually found that the smaller fragment has united distally to the normal position. Separation of the malunited bone is made with a small osteotome, and two small drill holes are than placed in the smaller fragment. This must be done with care, so as to avoid fragmentation. A drill hole is then made in the base of the metacarpal, from the dorsal to the volar surface. By abduction of the thumb and the application of pressure on the base to reduce the dislocation, the mortise is restored. Reduction of the fracture is maintained with a mattress suture of cotton, No. 24. This runs through the drill holes and is tied on the dorsum, after including the periosteum on each side, at the same time abducting the thumb (Fig. 3). This abduction and inward pressure of the base of the metacarpal must be maintained during the rest of the operation and the cast application, because there is a tendency for the dislocation to recur, owing to the contracted capsule on the radial side of the joint.

After closure, a gauntlet type of cast is applied, with the thumb included down to the interphalangeal joint. The cast is left on for four weeks, after which gradual active motion is begun.

which arise from the synovial membrane of the tendon sheath. These tumors, Morton states, are closely related to tumors of joints and bursae. If these lesions are neoplasms, they are certainly benign. As far as the writer knows, there has been no report of malignant degeneration or metastasis from these tumors.

The theory that xanthomata of tendon sheaths are of inflammatory origin was first proposed by Dor in 1898. Later writers supported his views. Mason and Woolston believed that these lesions represent a chronic inflammatory reaction to different irritants. Jaffe and his associates stated that xanthomata of tendon sheaths and synovial membrane represent an inflammatory reaction, the cause of which is unknown. They called attention to the presence of inflammatory elements, such as the phagocytic macrophages, collagen, and hyaline fibers, as evidence of the inflammatory nature of these lesions. They stated further that the inflammatory reaction is caused by neither repeated local hemorrhage nor bacteria. Cultures of the lesions showed no infectious organisms. Lipoid imbalance is also discounted by these authors as an etiological factor.

A disturbance in the metabolism of cholesterol has long been held as the underlying cause of xanthomatous tumors. Pinkus and Pick were the first to call attention to the hypercholesteraemia often associated with xanthomata. They stated that cholesterol infiltration takes place because of an increased cholesterol supply from the blood. Galloway, Broders, and Ghormley are firm adherents of this theory of cholesterol imbalance. They state that the primary factor in the pathogenesis of xanthomata of tendon sheaths and synovial membrane of joints, whether single or multiple, is a disturbance in the cholesterol metabolism. There is either an increase in the absolute value of the blood cholesterol or a change in the ratio of cholesterol to cholesterol ester. These authors believe that the contributory factors in the formation of xanthomata are trauma and infection at the site of the lesion. About 40 per cent. of their patients gave a history of trauma, and 23 per cent. had had local infections.

There are those who believe that hypercholesteraemia is an important factor in the pathogenesis of certain types of xanthomata, but not of all. Stewart divided these lesions into those which were associated with an elevated blood cholesterol and those which were not. Young and Harris differentiated two groups of xanthomata, histologically identical, but clinically different. There is the group described as "xanthoma tuberosum multiplex", in which, in addition to tumors of the tendon sheaths, there are multiple xanthomatous plaques or patches on the skin and on the eyelids. Hypercholesteraemia is almost always present in this group. (The first patient reported here, with a blood cholesterol as high as 800, would belong in this group.) Isolated xanthomata of tendon sheaths comprise another group. Patients with these lesions have normal blood cholesterols. (The second patient described in this paper, except for the slight increase in blood cholesterol, would fit into this group.) Young and Harris considered trauma as an important causative factor in the pathogenesis of isolated xanthomata. This differentiation of two types of xanthomatous lesions reminds one of the interesting analogy drawn by Morton between hypercholesteraemia and xanthomata of tendon sheaths, and hyperparathyroidism and solitary bone cysts.

The writer does not agree with the contention of Galloway, Broders, and Ghormley that an increase in the blood cholesterol or a change in the ratio of cholesterol to cholesterol ester is the primary etiological factor in the pathogenesis of xanthomata. Most patients with multiple xanthomata do have a high blood cholesterol. Rosenthal and Braunisch, however, reported a case of "xanthoma multiplex", in which the blood cholesterol was normal. Patients with isolated xanthomata, on the other hand, usually have a normal blood cholesterol. The cases reported by Mason and Woolston, Ragins, Young and Harris, and Jaffe, Lichtenstein, and Sutro had no increase in the blood cholesterol. It is clear, then, that, whatever the relationship between xanthomata and cholesterol metabolism, a high blood cholesterol is not a prerequisite for the formation of these lesions.

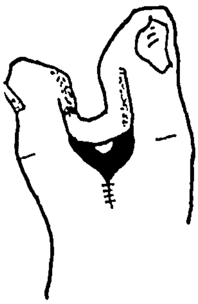

Fig. 5

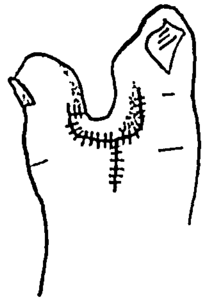

Fig. 6

Fig. 7

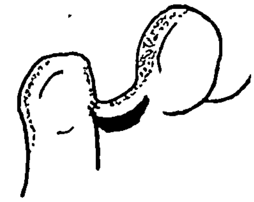

Fig. 8

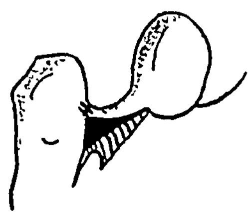

Fig. 9

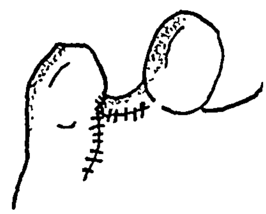

Fig. 10

Figs. 5 and 6: Suture of skin edges to each other and to flap. Note that web has been advanced.
Fig. 7: Plantar aspect; shows remaining defect.
Fig. 8: Method of raising flap.
Fig. 9: Flap has been raised.
Fig. 10: Flap has been mobilized and sutured.

skin flap, advancing the web distal to the underlying impinging normal bone. This operation has been performed on twenty toes, although the total number of patients was seventeen, as three cases were bilateral. All results were gratifying. In one case, necrosis developed in the flap; but the area became epithelialized and the web remained advanced.

The operation consists of (a) excising the painful interdigital clavus; (b) turning up a skin flap from the lateral aspect of the fourth toe; and (c) forming a sliding skin flap on the plantar aspect of the foot at the base of the fourth toe.

OPERATIVE PROCEDURE

Following excision of the soft corn on the fifth toe, a skin flap is turned up on the lateral aspect of the fourth toe, based distally, and is sutured to the distal edge of the skin from which the clavus has been removed (Figs. 1, 2, 3, and 4). Three interrupted silk sutures are sufficient for this step of the operation. The free dorsal edges of the wound on the fourth and fifth toes are then sutured together and to the free dorsal edge of the skin flap, forming a Y closure (Figs. 5 and 6). On the sole of the foot, from the base of the fifth toe in the lateral re-entrant angle of the still open plantar wound, an incision, three-quarters of an inch long, extending proximally, is made. The skin flap is then undermined and mobilized, thus simply effecting a closure of the plantar defect (Figs. 7, 8, 9, and 10).

The sutures are usually removed at the end of ten days. Frequent dressings are advised, beginning as early as the second day after operation. This keeps the wound dry and prevents maceration of the tissues, so common to the interdigital areas. With the operation described, convalescence is shortened. After removal of the sutures, the patient is able to walk without pain. After this operation, there is no possible danger of recurrence. In the experience of the authors, it offers distinct advantages over the conventional operation.

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apparent that the disc had bulged out into the foramen and had pressed the fifth root up against the pedicle and articular process of the fifth vertebra. When this pedicle had been partially removed, the response to tapping ceased. After the nerve roots had been covered with fat, a lumbosacral chip fusion was performed.

The patient remained in the Hospital about thirty-eight days and was last seen on July 10, 1946. His original complaints had entirely disappeared, and he was told to return to light work.

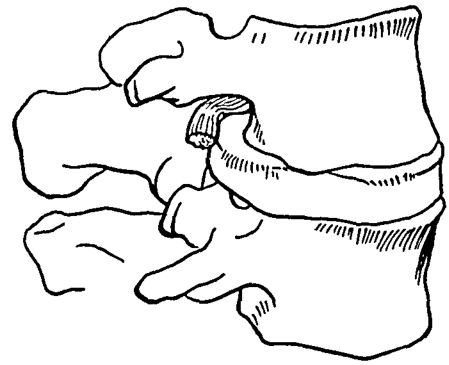

FIG. 1
Shows the mechanism of compression as found in Case 2.

In reviewing this case, the authors felt that this was the second case in which tapping on the articular processes revealed the site of pathological changes. It also showed a new mechanism of root compression,—namely, a compression of the nerve root in the foramen by a bulging disc which pressed the nerve root against the pedicle and articular process of the superior vertebra (in this case the fifth lumbar vertebra).

Many times, in performing what they consider to be a complete foraminotomy, the authors have removed a portion of the inferior pedicle. They feel that they have located, in this second case, a mechanism of foraminal-root pressure, formerly overlooked. Exploration with a probe or with a catheter and stylet would not reveal this type of compression in the foramen, because, in this case, there was plenty of room distal to the root in the foramen. It would seem that actual visualization of the nerve root and the disc in the foramen is necessary before one can consider a segment to be explored thoroughly.

These two cases illustrate the value of tapping on the articular processes to determine whether or not there is a compression of the roots in the foramina. Our present routine in operating upon the low-back region is, after the exposure of the spinous processes and laminae, to test the mobility of the segments exposed, and then to carry out the tapping procedure.

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some osteoclasts. In some cases the osteoblasts and other mesenchymal elements are of normal appearance, but in other cases the cells are big, irregular, and very numerous, with hyperchromatic nuclei which exhibit some mitosis. In the osteoid osteoma of the rib, the reactive periosteal bone was broken through in one area, although there was no invasion of the surrounding soft tissues. The osteoid osteoma is usually sharply demarcated from the surrounding sclerotic bone. Inflammatory cells are absent. Cultures for organisms, performed routinely in connection with the biopsies of these patients, have always been negative. All of the laboratory studies of the blood have also been negative.

Clinically and roentgenographically, the osteoid osteoma appears to be a lesion of inflammatory, rather than neoplastic, origin. This point of view was well elaborated and defended by Mondolfo in 1938 and by Brailsford in 1942. However, the typical histological appearance of the lesion, the complete absence of inflammatory cells, and the negative smear and culture make us believe, with Jaffe, that we are dealing with a benign neoplastic formation. There is no doubt that many cases, presented in the literature as proof that the osteoid osteoma is a lesion of inflammatory origin, are in reality examples of localized low-grade osteomyelitis and not of osteoid osteoma[2, 7].

This series indicates that the treatment of osteoid osteoma must be by an extensive block resection of the lesion, including a large portion of the surrounding sclerotic bone. The tumor and the symptoms have recurred in those patients whose lesions were treated by curettage or incomplete excision. The osteoid osteoma in the phalanx of one of the patients was excochleated twice, and recurred each time. On the other hand, in those patients whose lesions had been totally excised, the tumors did not recur and the symptoms completely disappeared.

Case 1, W. W. A twelve-year-old boy was seen in September 1944, complaining of pain in the lower left thoracic region and inability to straighten up. Both complaints were progressive, and had been present for nine months. The pain was dull and boring in character, and became worse at night. The patient's chest had been immobilized by binding with adhesive tape, which gave no relief. His past history and family history were non-contributory.

Physical examination revealed a long C curve of the spine, concave to the left, with an area of exquisite tenderness over the ninth left rib in the paravertebral area. The pelvis and shoulders were level, and the lower extremities were of equal length and circumference. All reflexes and sensations were physiological.

Two tuberculin tests, an agglutination test for Malta fever, and a Wassermann reaction were negative. The blood counts were normal. The roentgenograms showed expansion of the ninth left rib at the costovertebral junction. There was a central, irregularly dense nidus surrounded by a translucent ring, and some bone sclerosis (Fig. 1-A).

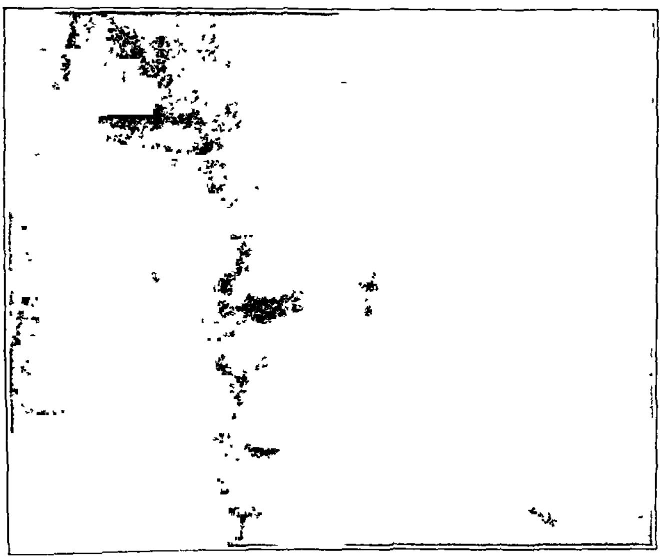

FIG. 1-A

Case 1, W. W. Osteoid osteoma of the ninth rib. Notice C curve and rotation of vertebra.

About five centimeters of this patient's rib was resected in November 1944. The tumor measured 1 by 2.5 centimeters, and was made up of a sclerotic, whitish, irregular bony mass. This was covered by normal-appearing but expanded cortical bone, which was slightly eroded in one small area. There was no gross evidence of inflammation, and cultures were negative (Figs. 1-B and 1-C).

Complete relief of pain was obtained, and the muscle spasm rapidly subsided with subsequent obliteration of the C curve. The patient was seen in July 1946 at the Clinic, and had no symptoms.

Case 2, L. M. An eleven-year-old white girl entered the Hospital on April 21, 1933, complaining of pain and swelling of the right ankle of nine months' duration. Both symptoms followed a minor twist of her ankle, were progressive in severity, and did not improve with rest. The pain was osteocopic in quality,

had no limp. She sought medical advice merely for cosmetic reasons. There was no history of injury to either leg. Her past history was essentially negative.

Physical examination was negative, except for the very unusual appearance of her legs. On the posterior aspect of each leg was a large bulging sausage-shaped mass, extending from the lower calf region to the heel (Fig. 1-A). The masses were hard and nodular, but not tender to palpation. On the right leg the mass measured 8 centimeters in width and 23 centimeters in length, and on the left side it measured 7 by 20 centimeters. There was no restriction of plantar flexion or dorsiflexion in the ankle joint. No other tumor masses or nodules were found. A roentgenogram of the leg showed no bone changes. A diagnosis of bilateral xanthoma of the Achilles tendon was made.

The blood count and urine were normal. The blood cholesterol was 245 milligrams and the cholesterol esters 142 milligrams per 100 cubic centimeters.

On December 9, 1943, both Achilles tendons were explored. Each tendon was about five or six times its normal size. The entire tendinous structure was infiltrated by sclerotic, bright yellow fibrous tissue, and was studded with nodules of varying sizes and shapes (Fig. 1-B). The nodules presented a variety of shades including golden yellow, ocher yellow, and yellowish brown. No normal tendon tissue was present. On the surface of the lower part of the tendon were two or three areas of softening, with a caseous consistency. The greater part of the tendon was cut away in the frontal plane, so that the remainder approached the normal size. Wound healing was delayed until four weeks after the operation. The patient gradually began weight-bearing, and six weeks after the operation she was sent home.

On subsequent follow-up visits to the Out-Patient Clinic, the patient complained only of mild ache and pain in the calves. There was some tenderness and induration along the lower part of the Achilles tendons, and slight shortening of the heel cords. When last seen, in June 1945, the patient had no pain and no limp. There was only slight residual equinus deformity. She was able to stand on her toes. The Achilles tendons were slightly enlarged, but they apparently had not increased in size since they were resected.

The histological examination of the tumors revealed a lobulated structure, containing large deposits of cholesterol. In some areas, the cholesterol deposits were surrounded by multinucleated giant cells. The lobules were demarcated by a proliferation of a collagenous type of connective tissue, which was more or less acellular except for the regions adjacent to the blood vessels. In these areas, the collagenous tissue was more cellular; and imbedded among the fibers were small nests of foam cells. In the periphery of the nodule, the tissue was more cellular and contained numerous large nests of foam cells.

HISTORICAL REVIEW

The first report of a true giant-cell tumor of a tendon sheath was made by Broca, in 1860; he described a lesion on the hand of a twenty-year-old woman. Czerny, in 1869, re-

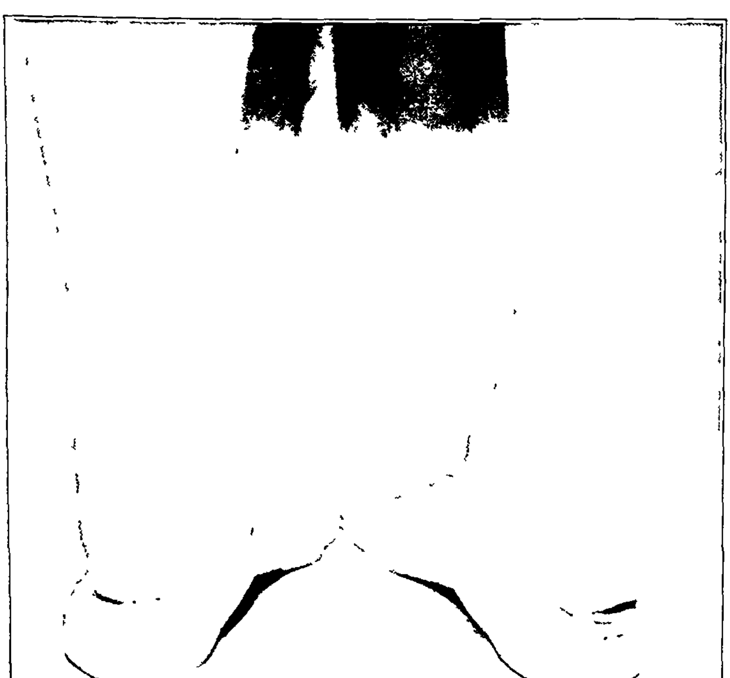

Fig. 1-A

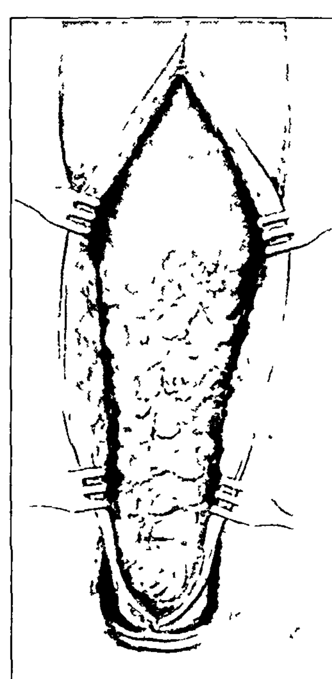

Fig. 1-B

Fig. 1-A: Case 2. Photograph of tumor of Achilles tendon.
Fig. 1-B: Appearance of Achilles tendon at time of operation.

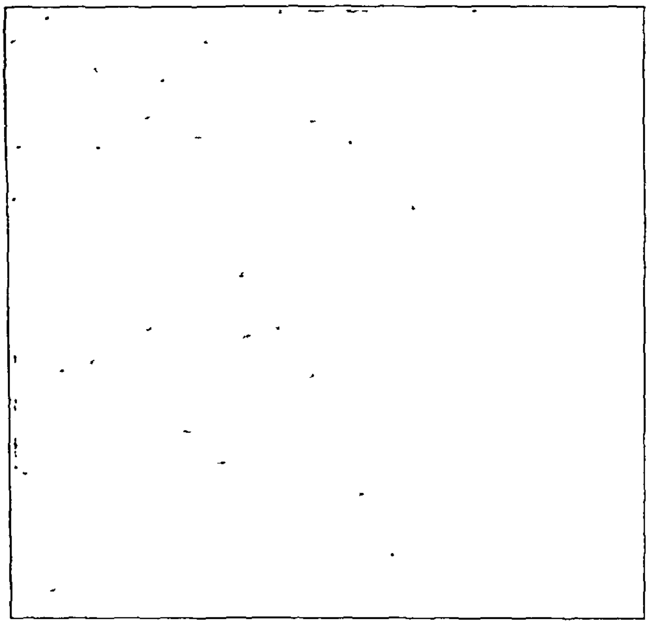

Fig. 2-A Fig. 2-B

Case 2, L. M. Roentgenogram and photomicrograph of an osteoid osteoma of the calcaneus. (*Fig. 2-A reproduced by permission of American Medical Association from Archives of Surgery*[3].)

The tuberculin test and a Wassermann test were negative. Blood counts were normal. Roentgenograms showed a lesion in the anterosuperior portion of the calcaneus with a dense central nidus, surrounded by a translucent ring and a zone of reactive bone sclerosis (Fig. 2-A).

The lesion was considered to be inflammatory. At operation on May 1, 1933, the cartilage over the anterosuperior surface of the calcaneus was found to be eroded, and the underlying bone was dark red. No pus was encountered. The lesion was curetted out and the wound was closed, but no relief was obtained. Subsequent roentgenograms revealed that the lesion was still present. A block resection, with fusion of the subtalar joint, was done on November 11, 1935. A sclerotic area was seen in the anterior portion of the calcaneus. The

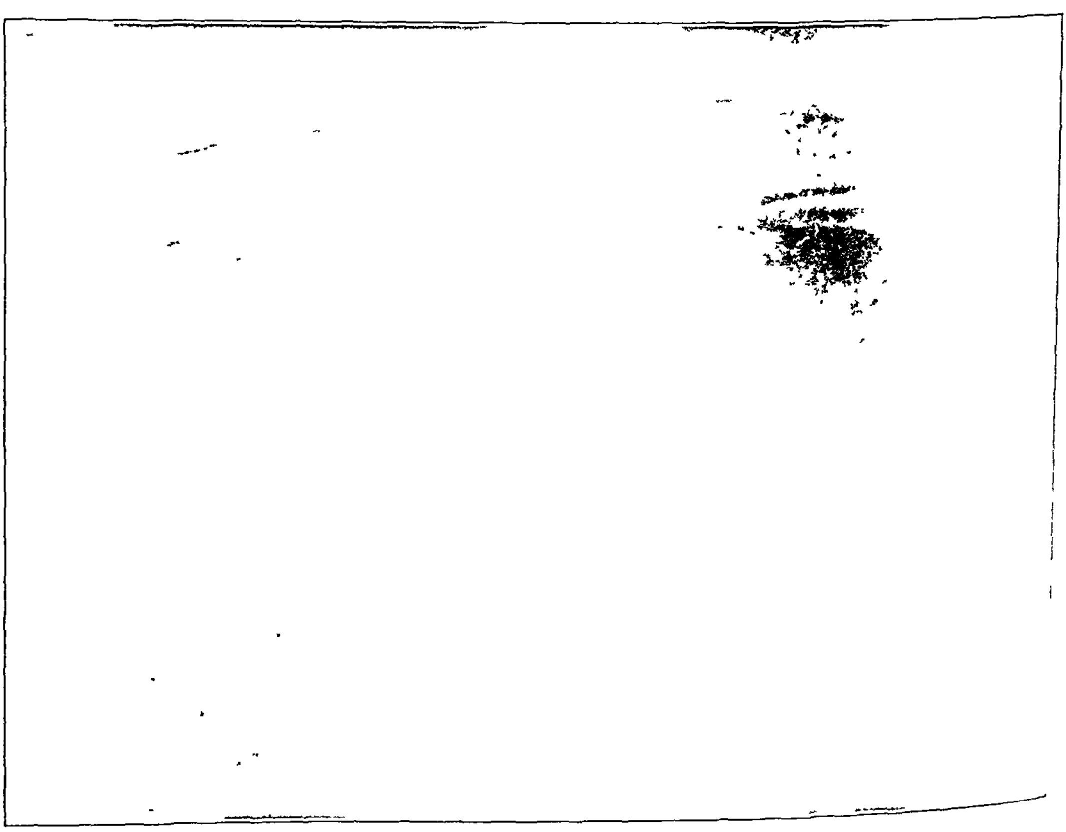

Fig. 3-A

Case 3, F. S. M. Roentgenograms of an osteoid osteoma of the tibia.

DURATION

Xanthoma of the tendon sheaths grows rather slowly. The duration of the lesions varied from one month to twenty-eight years, the average duration being about five years. In most cases, there was no pain or disability. The patient sought medical attention chiefly for cosmetic reasons. Pain and interference with function were occasional symptoms, caused by impingement of a nerve or the large size of the lesion.

PATHOLOGICAL FINDINGS

Grossly, these lesions are lobulated, well encapsulated, and have a firm fibrous consistency. They often present a variety of shades from yellow to yellowish brown, which are the result of deposits of lipoid and hemosiderin. The cut surface is hard. Fibrous strands extend from the capsule into the tumor, dividing it into lobules.

Microscopically, certain elements are almost invariably present,—that is, the typical xanthoma or foam cells, stroma cells, giant cells, fibrous tissue, cholesterol, and hemosiderin deposits. The xanthoma cells vary in number in different parts of the lesion. This cell has a foamy or bubble-like cytoplasm, with a small round pyknotic nucleus. The foamy appearance of the cytoplasm is due to intracellular lipoid deposits, mainly cholesterol. The stroma cell, spindle or oval in shape, has a faintly pink homogeneous or slightly granular cytoplasm and a pale oval nucleus. This cell resembles an endothelial cell. A few small globules of fat may be seen in the stroma cells. De Santo and Wilson, by means of fat stains, found various stages of transition of these stroma cells into foam cells. They state that "the foam cells are merely stroma cells laden with cholesterol". Similarly Jaffe, Lichtenstein, and Sutro believe that the stroma cells take up lipoids and become transformed into foam cells and even giant cells. Giant cells vary greatly in number in different lesions. They are essentially phagocytes and they are found mainly near areas of hemorrhage, deposits of blood pigment, or cholesterol. These giant cells resemble those of giant-cell tumors of bone. The nuclei vary in number from five to forty or more. The nuclei are so similar to those of stroma cells that most writers believe that the giant cells are derived from stroma cells, probably from a fusion of the latter.

Hemosiderin is found as yellow or brown particles in all three cell types, mainly intracellularly and occasionally extracellularly. The amount of hemosiderin present depends upon the amount of local hemorrhage and resulting disintegration of red blood cells. Cholesterol and its fatty-acid esters, found mainly intracellularly in the foam cells and to a lesser extent extracellularly (cholesterol clefts), constitute the chief fat content of xanthomata. Ragins states that the cholesterol is liberated by the degeneration of red blood cells, following hemorrhage into the tumor. De Santo and Wilson state that, just as the cholesterol causes the transformation of stroma cells into foam cells, so the hemosiderin changes the stroma cells into pigmented cells (macrophages).

One concludes, therefore, that the three important cell types of xanthomatous lesions are all closely related, and that the stroma cell is the "mother cell" of the foam cell and the giant cell. The stroma cell resembles an endothelial cell and is undoubtedly derived from the reticulo-endothelial system. The affinity of reticular cells for fat and pigment particles was shown long ago by Aschoff and his followers. Anitschkow, one of Aschoff's pupils, produced foam cells by feeding cholesterol to rabbits. He also showed that the same cells which changed into foam cells also took up dyes.

PATHOGENESIS

The nature of xanthomatous lesions of the tendon sheaths has long been a subject of controversy. They have been described as true neoplasms, as inflammatory lesions, as representing reaction to local trauma or infection, and as the result of a disturbed cholesterol metabolism. King, Morton, and Ragins believe that xanthomata are true neoplasms,

and cultures were negative. The pain was not relieved, and subsequent roentgenograms showed that the process was still present. A block resection was performed in May 1942. This block was formed of markedly sclerotic cortical bone, with a central nidus of softer, irregular bony material. Cultures and smear again were negative. A typical osteoid osteoma was discovered during the microscopic study of the material obtained at both operations. Complete relief of pain was obtained after the second operation. The patient was last seen in June 1946, and was entirely free of symptoms.

Case 4, D. S. A two-year-old girl was seen on April 21, 1933. Her parents stated that she had been restless and had had a lump on her left leg for one year. These symptoms were progressing. For the last six months the child had limped after her afternoon nap until she "limbered up". Her past history and family history were non-contributory.

Physical examination disclosed a fusiform, uniformly hard swelling over the upper third of the anteromedial aspect of the left tibia. There was slight increase of local heat, but no discoloration. Atrophy of one inch was present in the left thigh. The patient had free and painless motion of the hip, knee, and ankle. There was a medial bowing of the tibia.

The tuberculin and Wassermann tests were negative. Blood counts were normal. The roentgenograms showed a cortical nidus with a wide zone of reactive sclerosis on the anteromedial surface of the upper third of the left tibia (Fig 4-A).

The lesion was considered to be inflammatory. An Orr drainage was performed on May 1, 1933. The bone was sclerotic and no pus was obtained. Smear and culture were negative. Pain was relieved for one year, and then recurred. Subsequent roentgenograms revealed that the lesion was still present. A block resection of the area was done on June 4, 1934. A cavity containing a fingernail-sized "sequestrum", but no pus, was encountered. Examination of the pathological specimen disclosed the supposed sequestrum to be an osteoid osteoma. Complete relief of pain was obtained after the second operation. The patient was last heard from in March 1946, and had no symptoms.

Case 5, P. J. B. A nine-year-old girl was seen in May 1942, complaining of a painful enlargement of her right index finger of one year's duration. The patient stated that there had been very little pain at first.

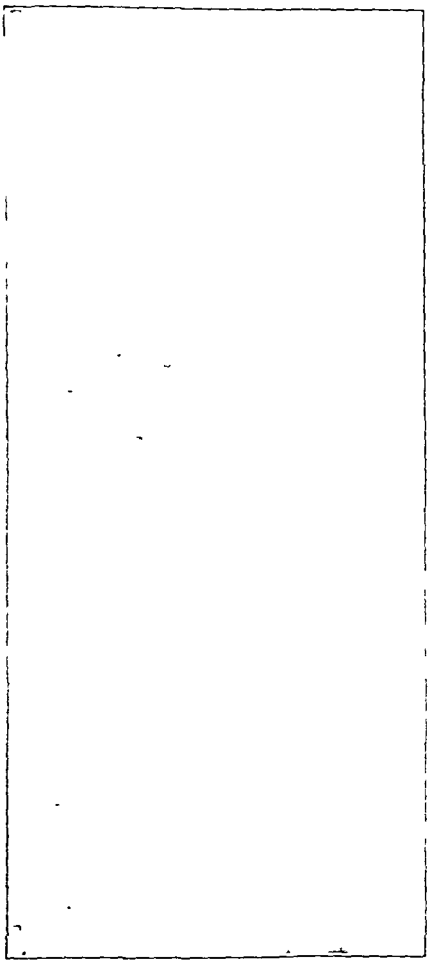

Fig. 4-A

Fig. 4-B

Case 4, D. S. Roentgenogram and photomicrograph of an osteoid osteoma of the medial aspect of the tibia. Notice the medial bowing of the tibia.

The writer believes that xanthomata are the result primarily of a disturbed cholesterol metabolism. He believes, however, that this is a *local cellular* disturbance, and not a generalized one associated with hypercholesteraemia. Thannhauser and Magendantz were the first to propose the theory of a local cellular disturbance of cholesterol metabolism as the underlying cause for the pathogenesis of xanthomata. They stated that "essential xanthomatosis is a cellular disease of reticulum cells caused by an intracellular disorder of their cholesterol metabolism". This theory of a local disturbance of cholesterol metabolism differs from the hypothesis of a generalized cholesterol imbalance in the concept of a primary intracellular disturbance of cholesterol metabolism, rather than an extracellular excess of the lipoid in the blood stream, causing a secondary deposition of cholesterol in the reticulo-endothelial cells.

Thannhauser and Magendantz classify xanthomatous disease under three main groups: (1) primary essential xanthomatosis, (2) secondary xanthomatosis, and (3) localized xanthoma-cell formation in true tumors. They divide primary essential xanthomatosis into two types,—first, the hypercholesteraemic type, to which belong xanthomata tuberosa of the skin and xanthomata of tendon sheaths; and, second, the normocholesteraemic type, to which belong the isolated osseous xanthomata of the skull and pelvis. This writer would add, to the normocholesteraemic type, the isolated xanthomata of tendon sheaths. Histologically the lesions are the same as in the hypercholesteraemic and normocholesteraemic types. The underlying etiological factor in both of these groups, according to Thannhauser and Magendantz, is an intracellular disturbance of cholesterol metabolism. They state that secondary xanthomatosis, as exemplified by xanthoma diabeticorum, is a symptom of lipaemia. Xanthoma diabeticorum also differs from essential xanthomatosis histologically. In the former condition, there are no foam cells and the cholesterol is *extracellular*. As further evidence in support of their theory of an intracellular metabolic disorder of the reticular cells, Thannhauser and Magendantz point to the formation of xanthoma cells in localized tumors, such as nevoxantho-endothelioma and fibrosarcoxanthoma, lesions which are entirely unrelated to essential xanthomatosis.

Another factor in the pathogenesis of xanthomata of tendons is trauma,—usually not sudden, severe trauma, but rather minor repeated injuries. All of the lesions of the Achilles tendons described here had their origin in the lower part of the heel cord, which is subject to constant repeated traumata from the back of the shoe. The fact that the majority of xanthomata of the tendons are found on the wrist and fingers, which are constantly subject to minor repeated injuries, would also point to the importance of trauma as an etiological factor in the formation of these lesions. Galloway, Broders, and Ghormley found a history of trauma in about 40 per cent. of their cases, and Mason and Woolston found a definite history of injury in approximately 60 per cent. of their patients.

TREATMENT

The treatment of xanthoma of the tendon sheath is excision. Most lesions may be completely removed without interfering with the tendon, but in a few cases where the lesion is large and involves the entire tendon, as in the cases presented here, the tendon must be excised. Recurrences are not uncommon. The incidence of recurrence in the cases reported in the literature has been from 12 to 15 per cent. These recurrent lesions should also be excised. Amputation is rarely resorted to. A few of the recurring lesions respond to deep roentgenotherapy, and this may be used to prevent recurrences; but, in general, roentgenotherapy is of doubtful value. It is used chiefly as an adjunct to surgery, when the entire lesion cannot be removed.

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Fig. 6-A

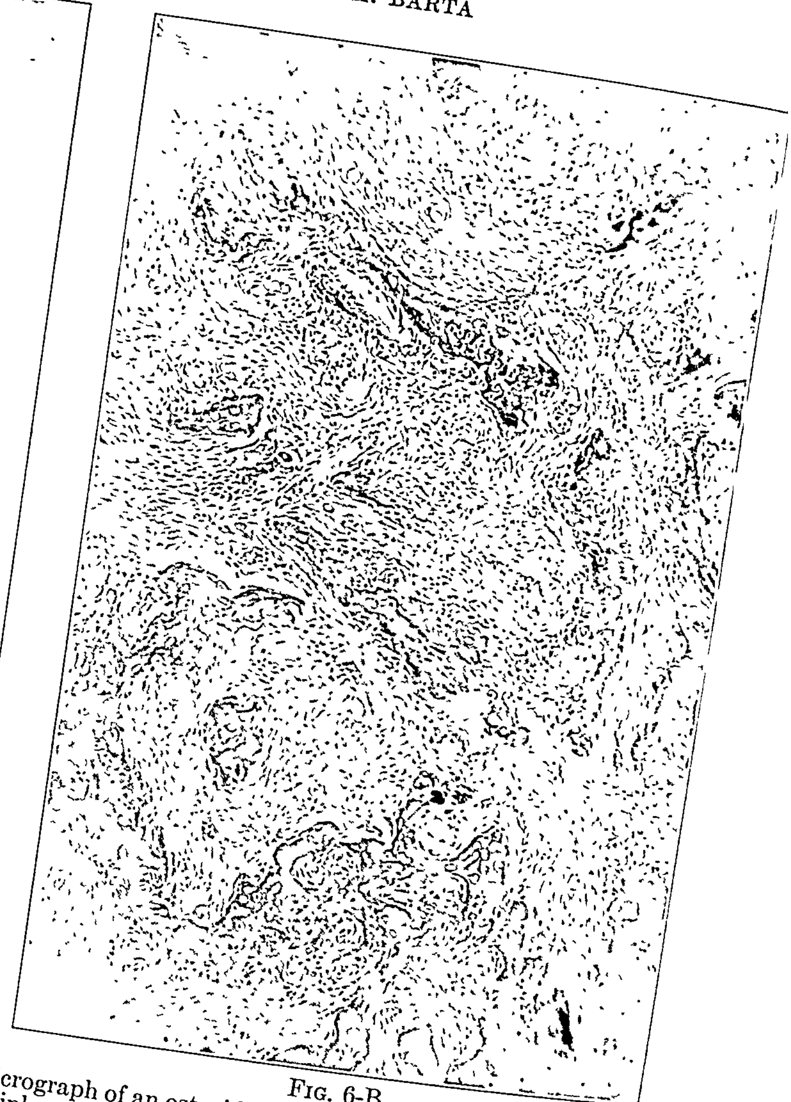

Fig. 6-B

Case 6. J. S. G. Roentgenogram and photomicrograph of an osteoid osteoma of the distal end of the fibula. The photomicrograph was taken from the periphery of the nidus. Notice the abundance of fibrous tissue.

Case 7. D. W. An eight-year-old boy entered the Hospital in January 1936, complaining of intermittent and progressive osteocopic pain of eight months' duration in the left hip. The patient stated that he fell down several cement steps and injured his groin at the onset of his present illness. His past history and family history were non-contributory.

Physical examination disclosed a slight, very tender swelling just below the lateral aspect of Poupart's ligament. All motions of the hip were painful. The range of motion, however, was complete, except for the absence of external rotation. There were no contractures. Atrophy of seven-eighths of an inch was found in the left thigh.

The Wassermann test was negative. The human tuberculin test, 0.1 cubic centimeters in a dilution of 1 to 1000, was positive. The white blood count was 14,600. The roentgenograms showed a destructive lesion in the ilium, just above the acetabulum, with irregular spotty areas of density. This lesion was sharply outlined by an area of bone sclerosis. The periosteum appeared to be elevated.

A block resection, through a Smith-Petersen approach, was performed in January 1936. At operation, the periosteum over the mass could not be stripped. A walnut-sized grayish-white area of soft, dense cancellous bony tissue, which gave the impression of a porous soapstone, was excised. This mass was well defined, and had a smooth outline of sclerotic bone. The smear and culture were negative. Complete relief of pain was obtained. The patient was last seen in December 1939, and had been completely free from symptoms.

Chest roentgenograms of this patient in May 1936 revealed hilar tuberculosis, which was probably active. Subsequent roentgenograms were interpreted as showing healed hilar tuberculosis.

SUMMARY

Of seven patients seen in the University of Iowa Hospitals, each having an osteoid osteoma, one represents the first published report of this condition in a rib. The ages of the patients varied from fourteen months to twelve years. The main clinical symptom was localized pain of from several months' to one year's duration.

OSTEOID OSTEOMA

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Seven patients, studied in this Clinic, had bone lesions which clinically, roentgenographically, and histopathologically corresponded exactly to the neoplastic lesion designated as "osteoid osteoma" by Jaffe[3]. All of these patients have now been followed for over two years.

One patient had osteoid osteoma in a rib; this is the first published report of an osteoid osteoma in such a location. A second patient of the authors' series had osteoid osteoma in the calcaneus. A report of this case was published by Jaffe (Case 2) [3] in his original paper on this condition. The lesions in the next two patients were located in the proximal half of the tibia. In the remaining three patients, the bones involved were the middle phalanx of the right index finger, the lower half of the left fibula, and the left ilium, just above the acetabulum.

Three patients of this series were males and four were females. Their ages ranged from fourteen months to twelve years. The patients gave histories of osteocopic pain of slow onset, usually intermittent in character, and not relieved by rest; this pain had been present from three months to one year. These symptoms followed minor traumata in only two cases If the lesion was in the cortical portion of a bone and was located superficially, an expansion of the cortex of the bone appeared within two or three months after the onset of pain.

On physical examination, a small area of exquisite tenderness could always be detected. In five patients, slight local swelling was present over the elevated and tender area. The patients had no fever, although a slight local elevation of temperature was noticed in two cases. Some limitation of motion and muscle spasm were noted, if the tumor was located close to a joint. Some patients, with osteoid osteomata located in the bones of the lower extremities, had decided limps. Moderate regional muscle atrophy was seen, if the condition was of long standing.

In addition to these general symptoms, peculiar deformities were noted in three patients. The patient with an osteoid osteoma in the posterior end of the ninth left rib (Case 1) had a right C curve of the spine, with marked limitation of motion, and pain and muscle spasm of the left sacrospinalis. A fourteen-month-old child (Case 6) was brought for consultation because of a progressive varus deformity of the ankle, produced by an osteoid osteoma in the lower third of the fibula. In the third patient (Case 4), an inward bowing of the tibia developed due to an osteoid osteoma in the inner aspect of the upper part of the tibia.

The osteoid osteoma appears on roentgenograms as a small nidus-like, circumscribed area (0.5 to 2.5 centimeters in diameter), either uniformly translucent or mottled with irregular and sclerotic bone. It is almost always surrounded by reactive new-bone formation, which is of moderate character when the lesion is located in spongy bone, but which becomes very pronounced when the osteoid osteoma is located in cortical bone. Usually the older the lesion, the more marked becomes this reactive bone sclerosis.

The histological picture of osteoid osteoma is unmistakable, although variations occur in the apparent aggressiveness of its cellular elements. The characteristic appearance is given by an irregular network of partly calcified osteoid trabeculae. Intermingled in this network is vascular and very cellular connective tissue with abundant osteoblasts and

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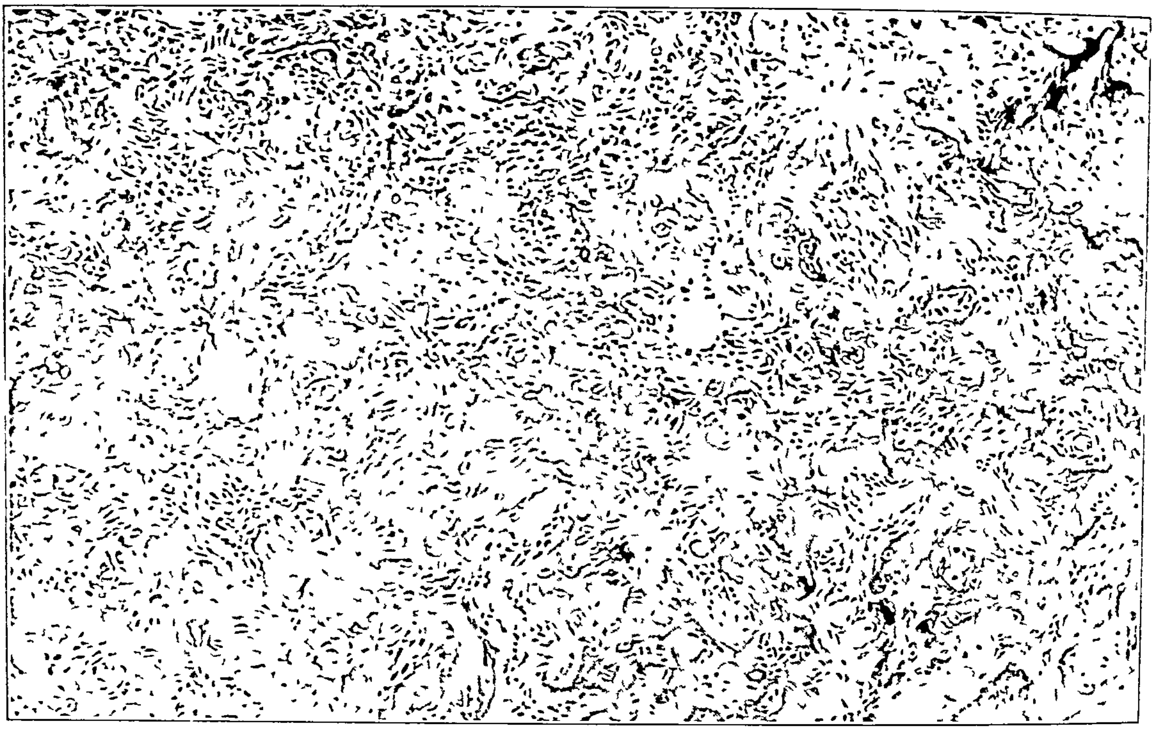

FIG. 7-C
Case 7. Low-power photomicrograph of specimen shown in Fig. 7-B.

Peculiar deformities, produced by the presence of the osteoid osteoma, were noted in three patients. The patient with an osteoid osteoma in a rib had a total C curve of the spine which improved and finally disappeared after the removal of the lesion. A fourteen-month-old child had a varus deformity of the ankle, produced by an osteoid osteoma in the lower end of the diaphysis of the fibula. The osteoid osteoma in this patient had evidently stimulated the growth of the lower epiphyseal plate of the fibula. An inward bowing of the tibia developed in the third patient, due to an osteoid osteoma in the inner aspect of the upper portion of the tibia.

Mainly because of the typical histological appearance of the lesion, the authors believe, with Jaffe, that the osteoid osteoma is a benign neoplastic formation.

Three patients (Cases 1, 6, and 7) were cured by block resection of the osteoid osteoma and surrounding area. In three patients treated by curettage of the involved area, the lesion recurred (Cases 2, 3, and 4) and had to be resected in a second operation. The osteoid osteoma in the phalanx of one patient was excochleated twice and recurred. The roentgenograms of this lesion have not shown essential changes in over four years.

The authors' experience indicates that the treatment of the osteoid osteoma must consist of an extensive block resection of the lesion, together with removal of a good deal of the surrounding sclerotic bone.

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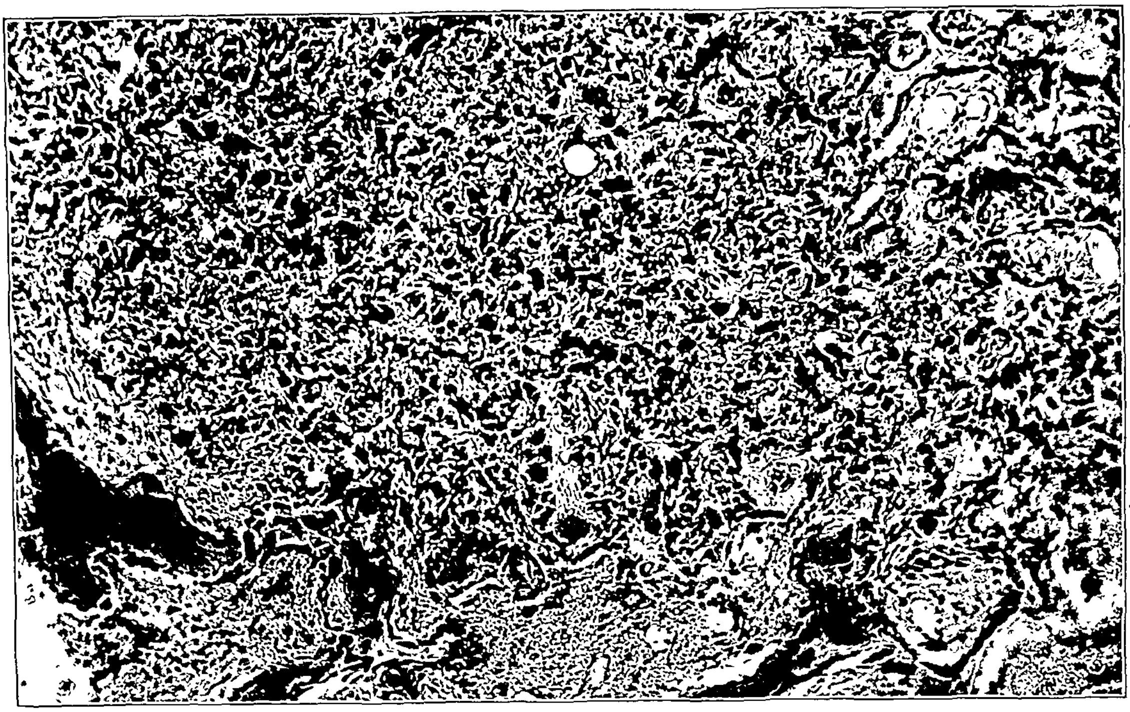

FIG. 1-B

Case 1. The low-power photomicrograph shows a very cellular osteogenetic connective tissue and osteoid trabeculae forming the nidus of the osteoid osteoma of the rib. The periosteal bone is broken, but the tumor does not penetrate it.

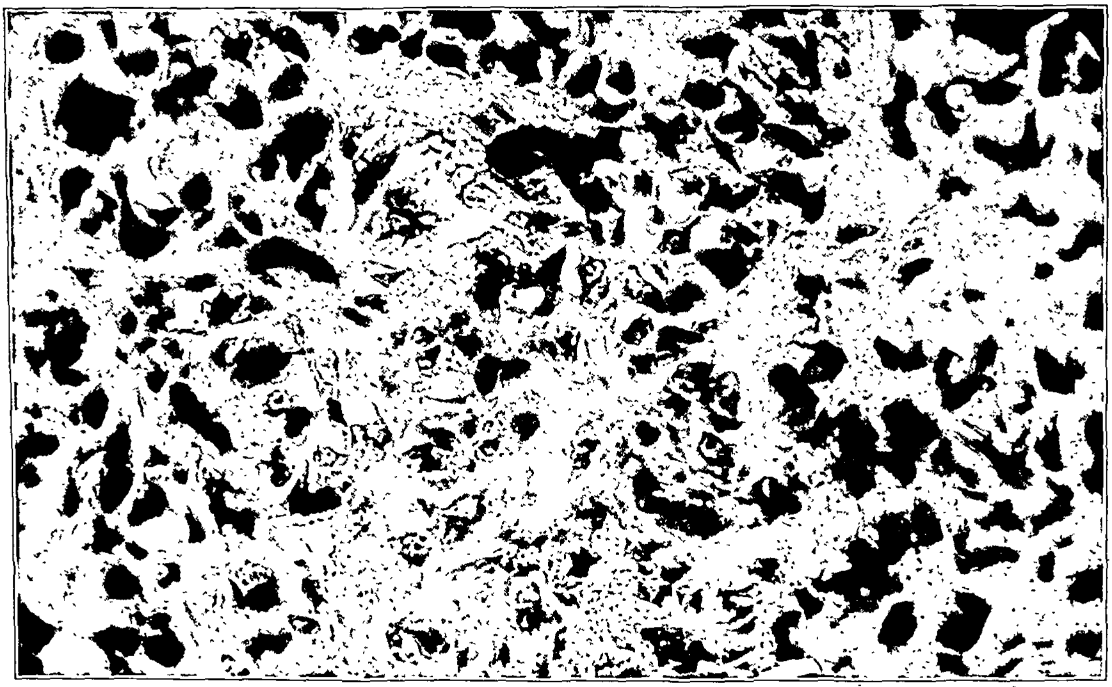

FIG. 1-C

Case 1. The high-power photomicrograph shows irregular osteoid trabeculae, and atypical and hyperchromatic cells.

and sedatives were required for sleep. Her past history and family history were non-contributory. Physical examination showed a diffuse swelling of the right ankle and hind part of the foot. There was atrophy of the thigh of five-eighths of an inch, and calf atrophy of three-quarters of an inch. The patient's range of ankle motion was limited, by pain and muscle spasm, to 10 degrees of dorsiflexion and 10 degrees of plantar flexion. Maximum tenderness was present over the sinus tarsi.

FIG. 1-A

FIG. 1-B

FIG. 1-A: Case 1. Preoperative roentgenogram showing area of increased bone density surrounded by area of diminished bone density in right carpal navicular bone.

FIG. 1-B: Roentgenogram June 18, 1946, sixteen months after operation, showing definite osseous union of remaining fragments of carpal navicular.

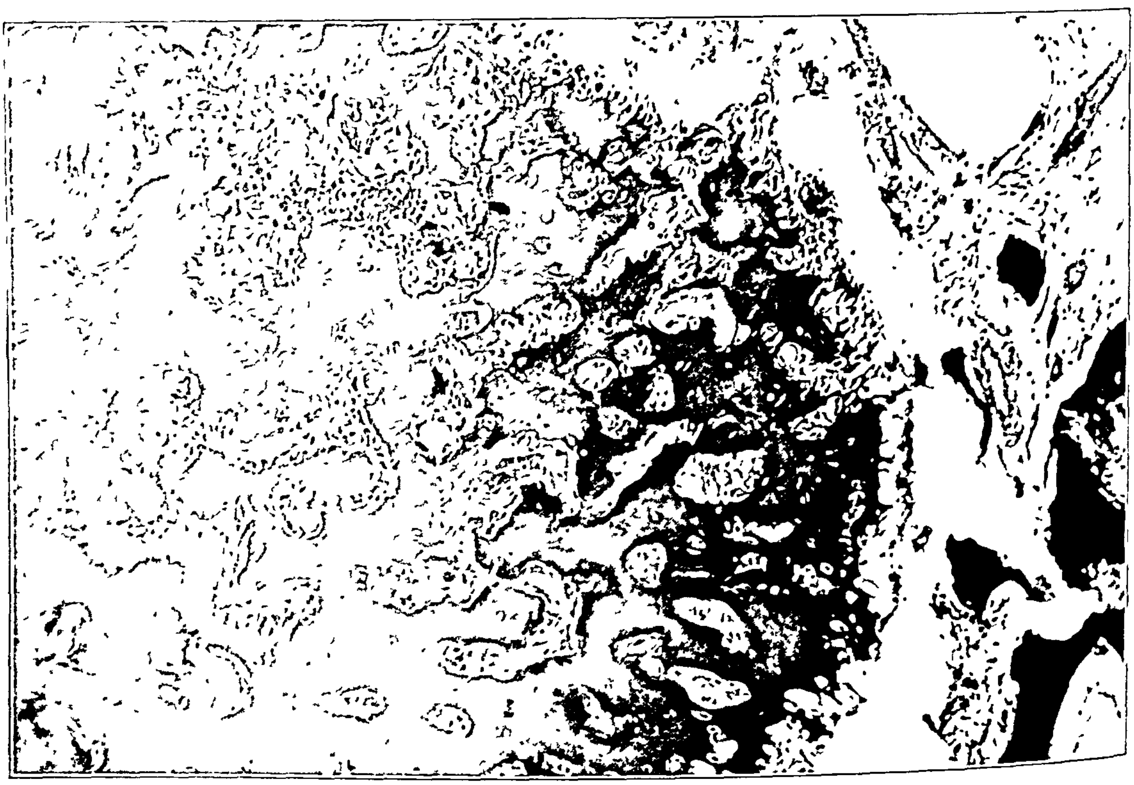

FIG. 1-C

Osteoid tissue predominates microscopic picture.

very thick-walled blood vessels, whose lumina are markedly reduced. In addition, the marrow spaces contain a moderate sprinkling of inflammatory cells.

Diagnosis: "Osteoid osteoma of the navicular bone. (Army and Navy General Hospital accession number S-49-45. A. M. M. accession number 129817.) The culture was negative, as was the smear."

CASE 2. A twenty-two-year-old white male was transferred to the Hospital on February 25, 1945. His history disclosed that for the past two years, there had been periodic pain with slight swelling over the radiodorsal aspect of the right wrist. Prior to induction into the Service, he had sought medical advice and treatment for this condition. He reported to sick call May 27, 1944, and on July 6, 1944, a biopsy specimen was taken from the joint and a spur was removed from the side of the navicular bone. This operative procedure did not relieve the pain.

Physical examination of the patient was negative, with the exception of the right wrist. The scar from th

bone was very hard and the marrow was evidently fibrous. Complete relief of pain was obtained. The histological picture of the material obtained at both operations was identical, and revealed a typical osteoid osteoma. The patient was last heard from in November 1937, and was entirely free of symptoms.

Case 3. F. S. M. An eight-year-old boy entered the Hospital in November 1940, complaining of dull, boring, intermittent pain just below his right knee, which was worse at night. This pain had been present for three and one-half months, and was increasing in severity. There was no history of trauma. His past history and family history were non-contributory.

Physical examination disclosed a slightly swollen, hard area in the upper third of the right leg, over the lateral border of the tibia. There was exquisite tenderness to the right of the tibial tubercle, with a sense of increased heat in this region. Atrophy of one-half inch was noted in the right thigh. The patient's gait was normal.

FIG. 3-B
Case 3. Section of gross specimen removed.

The tuberculin test and Wassermann test were negative Blood counts were normal. Roentgenograms disclosed a translucent, irregular area in the anterolateral cortex of the tibia, surrounded by a zone of bone sclerosis (Fig. 3-A).

The lesion was considered to be inflammatory, and the Orr method of drainage was carried out in November 1940 Dense sclerotic bone, with a small area filled with a putty-like substance, was found. Smear

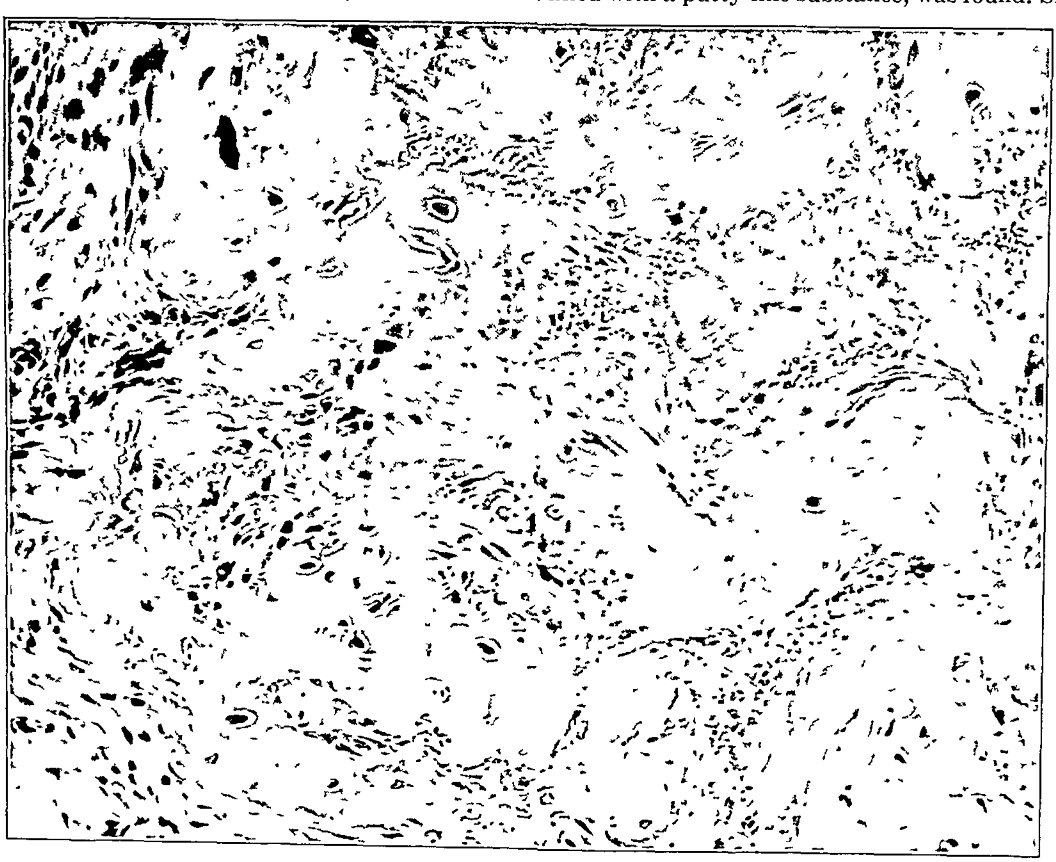

FIG 3-C
Case 3. Photomicrograph of specimen shown in Fig. 3-B.

The pathologist's report was as follows:

Gross: "There are four specimens. The first specimen consists of irregular small fragments of grayish-white and yellowish tissue. The second specimen is made up of two irregular fragments of dense bone. The largest measures seven by five millimeters. The third specimen consists of two small reddish-brown fragments, both of which contain spicules of bone. The fourth specimen consists of five pieces of reddish-brown tissue.

Microscopic: "In sections from the synovia, the synovial villi are more prominent than normal. In many places, the outer coat of synovial cells is lacking. The bulk of synovial villi consists of loose, fibrillar stroma in which are scattered large mononuclears, a rare lymphocyte, and occasionally a polymorphonuclear or plasma cell. Vascularity does not appear to be greatly increased. The capsular tissue contains a few focal collections of lymphocytes. These collections are small and do not possess germinal centers. The collagenized component is normal. The blood vessels show thickening of their walls with reduction of their lumina by intimal connective-tissue proliferation. Sections from the cortex of the navicular bone near the first lesion show a condensation of osseous bars. The osseous bars are invariably marginated by osteoblasts. There is a progressive intensification of osteoblastic activity, passing from the periosteal surface toward the inner margin. The osteogenic proliferation is likewise increased as the center of the specimen is approached. There is nothing to indicate inflammation. The periosteum is thickened by connective tissue and, to a less extent, by osteogenic-cell proliferation. In sections from the rarified area seen on the roentgenograms, the lesion consists of a nidus of densified trabeculae of highly atypical calcified bone. These calcified trabeculae are most irregular, varying markedly in size and shape. They appear to begin nowhere and end nowhere. In other words, they exhibit no definite pattern of mechanical alignment. The calcified trabeculae are separated and surrounded by proliferating osteogenic cells, which, for the most part, have advanced in differentiation to the stage of osteoid tissue. The irregularity of osteoid tissue is striking. Between the osteoid tissue are large numbers of osteoclasts, sometimes applied to the osteoid tissue and sometimes nearly surrounded by osteoid tissue. The osteoclasts vary considerably in size and shape. This osteoid tissue fades into more mature bone.

Diagnosis: "Osteoid osteoma of the navicular bone. (Army and Navy General Hospital accession number S-164-45. A. M. M. accession number 132457.) Smear and culture were negative."

DISCUSSION

In the first case, an osteoid osteoma was suspected preoperatively because of the roentgenograms. The clinical findings were not entirely those ascribed to this pathological entity. The patient had local signs of inflammation,—heat, redness, and swelling.

Of interest was the finding that surgical removal of a portion of the carpal navicular can be accomplished with impunity. The case has been followed for a period of nineteen months; osseous union of the remaining fragments is taking place, and it is probable that the man will have a durable wrist from the standpoint of function, since no arthritic changes have developed in the radionavicular joint.

In the second case, the difference in roentgenographic appearance—namely, osteolysis surrounded by increased bone density—is attributed to a different stage in the evolution of the process. This fact has been pointed out by previous authors. As the process develops, sclerosis of the bone dominates the characteristic roentgenographic findings, whereas earlier osteolysis with bone rarefaction is the rule. In this case, excision of the pathological portion, with the application of chip grafts, rather than excision of the entire navicular bone, was the indicated procedure. Removal of the navicular bone leaves a rather marked incongruity of the joint surfaces, and, if the wrist is used for even mild activity, traumatic arthritis may develop, which in turn may necessitate radiocarpal arthrodesis.

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During the previous five months, however, the pain had been dull and boring in character and progressive in severity, being worse at night. Her past history and family history were non-contributory.

Physical examination disclosed a hard, fusiform, tender enlargement over the distal portion of the proximal phalanx. There was no increase in local heat. Full motion of the finger joints was possible. The tuberculin and Wassermann tests were negative. Blood counts were normal. The roentgenograms revealed a dense central medullary nidus, surrounded by a translucent circle and a zone of bone sclerosis (Fig. 5-B).

An excochleation was done on May 18, 1942. The cortical bone was very hard, and the distal half of the marrow cavity was filled with a dense yellowish-white, irregular bony mass. No pus was encountered. A smear and culture were negative. Examination of the pathological section revealed a typical osteoid osteoma. The lesion and pain recurred shortly after the patient left the Hospital, and on August 10, 1942, she was operated upon again. A soft pinkish mass, which proved to be a recurrent osteoid osteoma, was removed from the medullary cavity. The patient was last seen on July 23, 1946. She has had no osteocopic pain since the second operation. The finger remained enlarged, however, and the patient has pain over the tumor with weather changes. Slight tenderness persisted upon compression of the mass. The roentgenograms revealed that the process was still present. Further surgery was advised, but was refused at that time because the patient was moving from the state.

Case 6, J. S. G. A fourteen-month-old girl entered the Hospital in March 1942, with a deformity of her left ankle which had been present since she began to walk, at the age of ten months (in November 1941). She had pain when shoes were tried on. Her past history and family history were non-contributory.

Physical examination showed lateral bowing of the lower thirds of the tibia and fibula. The patient complained when pressure was made over the fibula, just above the ankle joint. There was no increase in local heat, and no muscle weakness could be elicited.

Laboratory examinations revealed negative tuberculin and Wassermann tests. The blood counts were normal. Cholesterol determinations were 148 and 168 milligrams per 100 cubic centimeters. The total lipids were 811 milligrams per 100 cubic centimeters, and the lipid phosphorus was 5.4 milligrams per 100 cubic centimeters. Roentgenograms showed a translucent area in the lower part of the fibula, with varus of the lower parts of the tibia and fibula (Fig. 6-A).

A two-inch section of the fibula, one-half inch above the distal fibular epiphysis, was resected and osteotomy of the tibia was performed in July 1942. Grossly the lesion showed fusiform swelling and thinning of the cortex to eggshell thickness. On transection, an irregular cavity was found, filled with whitish calcareous tissue. The patient was last seen in May 1946. Her legs were equal in length, no deformity was present, and she had had no symptoms since the operation.

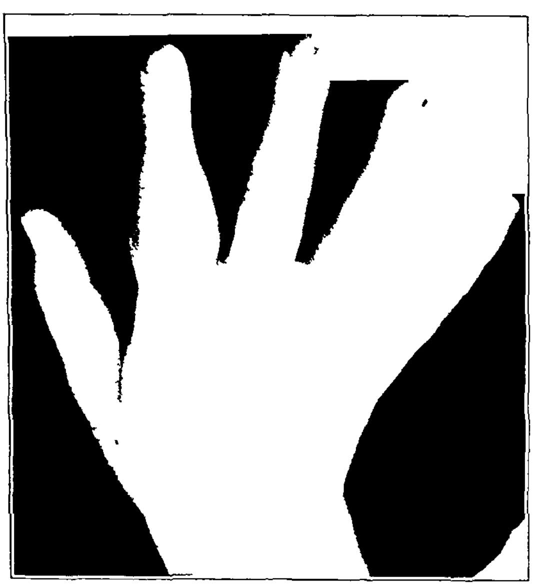

FIG. 5-A

Case 5, P. J. B. Photograph of hand on admission in 1942.

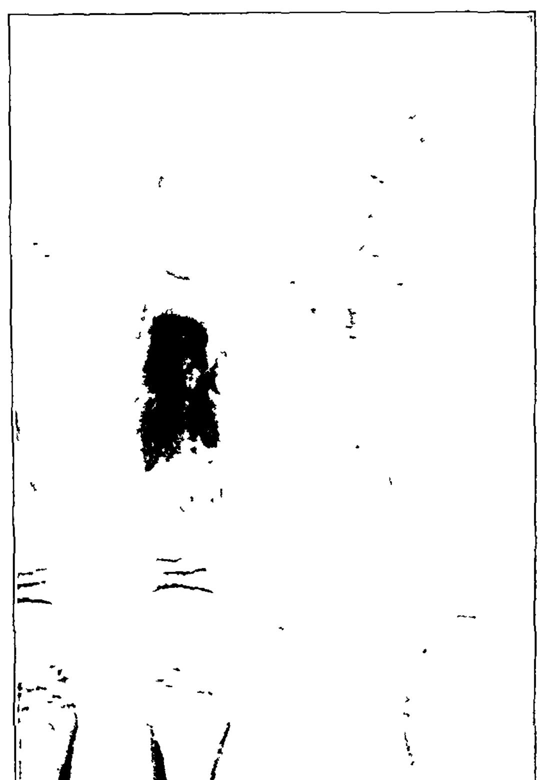

FIG. 5-B FIG. 5-C

Fig. 5-B: Roentgenogram on admission.
Fig. 5-C: Roentgenogram taken in July 1946. Notice that the nidus is still present.

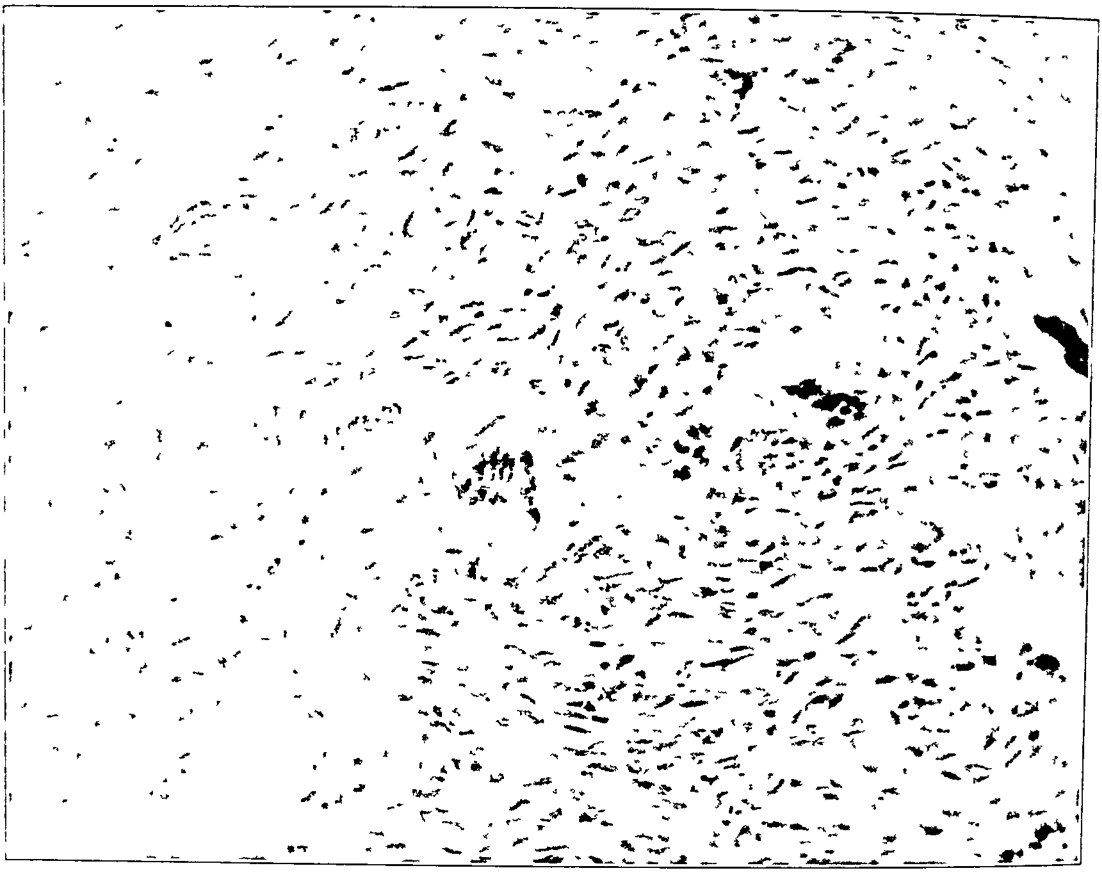

Fig 2

Photomicrograph (× 260) shows presence of giant cells. (*Negative No. 99261, Army Institute of Pathology*)

culture was made, and the abnormal tissue was removed. With a small ronguer, the superficial opening was enlarged and the periphery of the tumor was curetted. Upon irrigation of the defect with normal saline solution the surrounding bone appeared to be normal. The wound was closed and healed *per primam*

The tissue was submitted to the laboratories for microscopic examination and the report was as follows: "Examination of tissue submitted showed it to be made up of relatively cellular fibrous tissue, throughout which were scattered numerous multinucleated giant cells. A few spicules of bone were found These were degenerating and were surrounded by osteoclasts. Some inflammatory cellular infiltration was present *Diagnosis* Benign giant-cell tumor *Culture:* Negative."

The opinion of the Army Institute of Pathology, gathered from a series of slides sent to them, was as follows: "The picture, as seen in these slides, is considered to be one of reaction of bone tissue and bone marrow to injury. It is the consensus of the Staff that this picture differs in several respects from the accepted appearance of a true 'benign giant-cell tumor of the bone'. The giant cells, from which the tumor derives its name, are not nearly so conspicuous as one would wish, and the intervening stroma is composed of spindle cells showing a marked tendency to form collagen. In addition, there are a few areas in which osteoid formation with early calcification suggests regeneration of bone within the 'tumor tissue'. These features, together with the abundant pigment found throughout, suggest a reparative process following an injury, even though no history of trauma can be elicited. The unusual position of this lesion in the diaphysis, close to the cortex, also supports this conception, since the standard type of 'benign giant-cell tumor' is seen only within or near the metaphysis."

Convalescence was uneventful, the patient being seen at regular intervals in the Clinic. In April 1946 (thirteen months after curettage), roentgenograms of the right tibia were made and showed healing with dense cortical bone (Fig 4).

DISCUSSION

Cone, in 1928, described a case of ossifying hematoma. He called attention to trauma and hemorrhage, pointing out their etiological pathology. At that time, there was a confusion of terms as applied to calcifying hematoma, myositis ossificans, ossifying hematoma, and abnormal osteoclasia.

It is recognized that in this ossifying hematoma, proliferation of osteoclasts is brought

FIG. 7-A

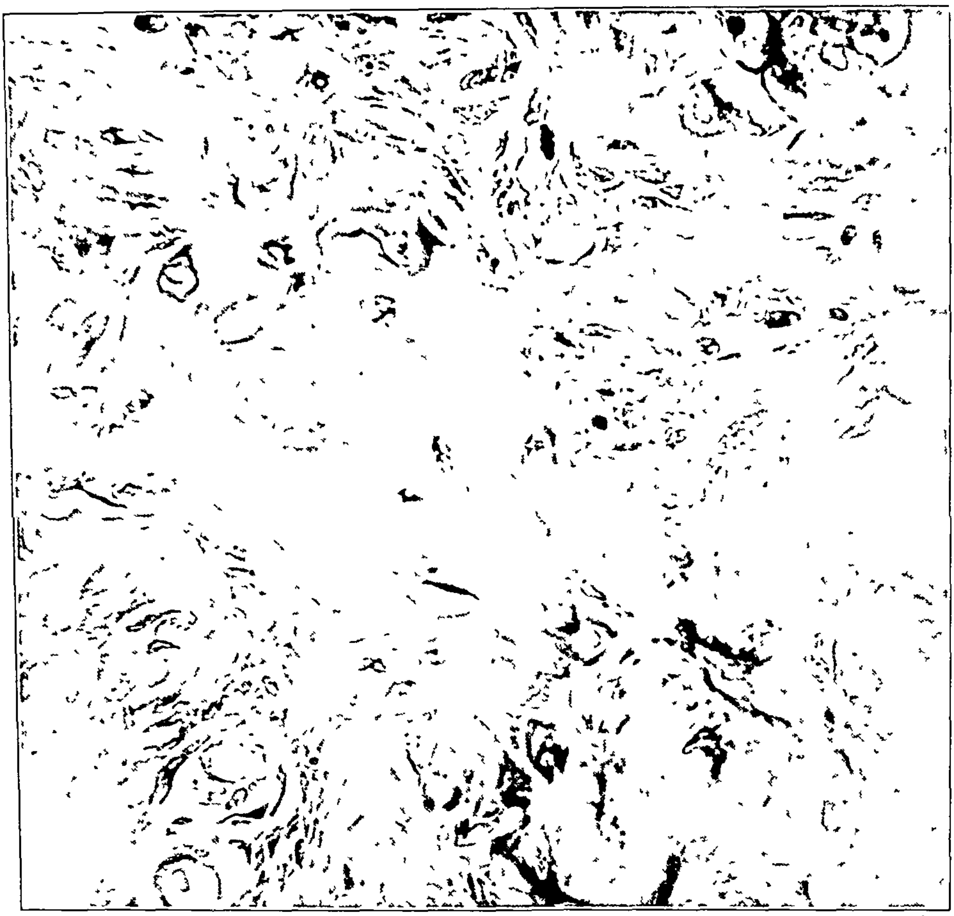

FIG. 7-B

Case 7, D. W. Roentgenogram and high-power photomicrograph of an osteoid osteoma of the ilium. Elevation of the periosteum is shown in the roentgenogram.

TABLE I

REVIEW OF CASES OF SUBPERIOSTEAL GIANT-CELL TUMORS REPORTED IN THE LITERATURE

Name of Author	Location of Lesion	Sex	Age (*Years*)	Duration (*Weeks*)	Treatment
Cone	Upper humerus	F	19	10	Excision
Geschickter and Copeland	Femur	M	17	6	Curettage
Geschickter and Copeland	Ulna	F	21	8	Excision
Geschickter and Copeland	Humerus	F	58	2	Curettage
Geschickter and Copeland	Humerus	F	16	8	Excision
Potts	Mandible	M	6	6	Excision
Present	Radius	M	33	8	Excision
Hodgen and Frantz	Tibia	F	15	16	Curettage

about by hemorrhage and a disturbance of the normal blood supply of the bone, sometimes leading to abnormal osteoclasia or giant-cell tumor. Geschickter and Copeland consider the initial events to be trauma and hemorrhage, followed by separation of the periosteum. In the cortex beneath the periosteum, a disturbance in periosteal blood supply occurs; in the periosteum itself, a healing reaction is stimulated. A mixture of giant cells and osteitis fibrosa results. The underlying cortical bone, however, possesses sufficiently active healing power to overcome any abnormal activity of osteoclasts and causes their rapid regression.

By roentgenogram, these lesions are seen in the diaphysis, casting little or no shadow and appearing as a scooped-out area within the cortex. There may be little or no periosteal reaction and an absence of medullary involvement.

The age group in this type, or variant, of the giant-cell tumor differs slightly from that of the usual epiphyseal type. Table I summarizes the eight cases taken from the limited bibliography.

The case here reported seems to be an example of subperiosteal giant-cell tumor, possessing the characteristics ascribed to this entity. Healing occurred in the cortical bone and was recorded by roentgenograms made thirteen months after the operation. Potts reported the lesion in his case to have healed with no recurrence two and one-half years after treatment by excision.

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SOME SURGICAL ASPECTS OF OSTEOID OSTEOMA

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Two patients with osteoid osteoma of the carpal navicular presented themselves at this Army General Hospital for treatment. Since, to our knowledge, osteoid osteoma occurring in the carpal navicular has not been described before in the English literature, the cases were considered of sufficient significance to be reported. Furthermore, the surgical problem in each was different, thus demanding different procedures.

The name "osteoid osteoma" was suggested by Jaffe in 1935, who described several features which he believed were essential to the diagnosis. Although the disease is more common in the long bones, it has also been found in the vertebrae, calcaneus, talus, and other small bones. Roca described a case of osteoid osteoma of the carpal navicular in which enucleation of the entire bone was performed.

CASE REPORTS

CASE 1. A white male, aged twenty-seven, entered the Hospital on January 8, 1945, complaining of severe pain on the radiodorsal aspect of the right wrist. He had sustained mild injury to the wrist in April 1944, while with the Armed Forces. The wrist had been taped for ten days, when treatment hád been discontinued. He performed limited duty until November 1944, when he was given a discharge. Heat had been applied with little relief, and pain was severe enough at night to prevent sleep. He had had no fever. Following his discharge from Service, he attempted many different jobs, but was forced to give them up because of pain, redness, and swelling in the radiodorsal aspect of the right wrist joint.

Physical examination was normal, with the exception of the right wrist. On palpation, there was definitely increased local heat and swelling. Even light digital pressure over the carpal navicular caused marked pain. Flexion and extension of the wrist were moderately limited, whereas radial deviation was impossible because of pain. Routine blood and urine studies were all normal. Roentgenograms (Fig. 1-A) revealed an oval area of increased sclerosis, measuring about three by five millimeters, and surrounded by an area of diminished bone density on the radial aspect of the right carpal navicular. The remaining carpal bones appeared normal, and there were no roentgenographic signs of recent or old trauma. It was believed that the area should be explored in an attempt to make a definite diagnosis. On January 20, 1945, a transverse incision in the line of cleavage of the skin on the radial side of the wrist was made. The navicular styloid was identified, and a very short distance from this, the oval area of white bone was encountered. A section was taken for biopsy. It was impossible to enucleate the sclerotic piece of bone with a small pointed periosteum elevator. A sharp chisel was, therefore, used to resect the abnormal bone with the adjacent normal bone in the shape of a triangle. After this pathological area had been removed, it was possible to bring the remaining fragments of the navicular together by gently extending the wrist and with slight radial deviation. The wound was closed with the hand in this position, and a plaster dressing was applied. The patient was hospitalized for approximately one month and then was discharged, but for a period of six months he was seen weekly for reapplication of plaster and periodic roentgenograms. An aluminum wrist splint was then worn for ten months, enabling him to work as a driver for a local grocery concern. Since the operation, he has had no pain whatsoever in the wrist. Roentgenograms taken in June 1946, sixteen months after the operation (Fig. 1-B), show early osseous union of the two fragments of the navicular bone. Immobilization is no longer necessary, and the wrist is now asymptomatic.

The report of the pathological examination was as follows:

Microscopic: "Sections [Fig. 1-C] show a circumscribed area composed of osteoid tissue and atypical calcified osseous spicules. At the periphery, the osteoid tissue is made up of acidophilic bars arranged in an anastomosing, lattice-like fashion. The interstices between these bars contain numerous osteogenic cells, some of which have differentiated into osteoblasts. The lacunae of the bars are large, and most of them are occupied by osteocytes. As the central portion of the lesion is approached, the tissue becomes much more compact with only occasional marrow spaces. Throughout the solid area are bluish-staining areas, representing calcified deposition. The area showing these changes is imbedded in cancellous bone. The surrounding bone exhibits no tendency to sclerosis; in fact, osteoporosis is present. The marrow space contains several

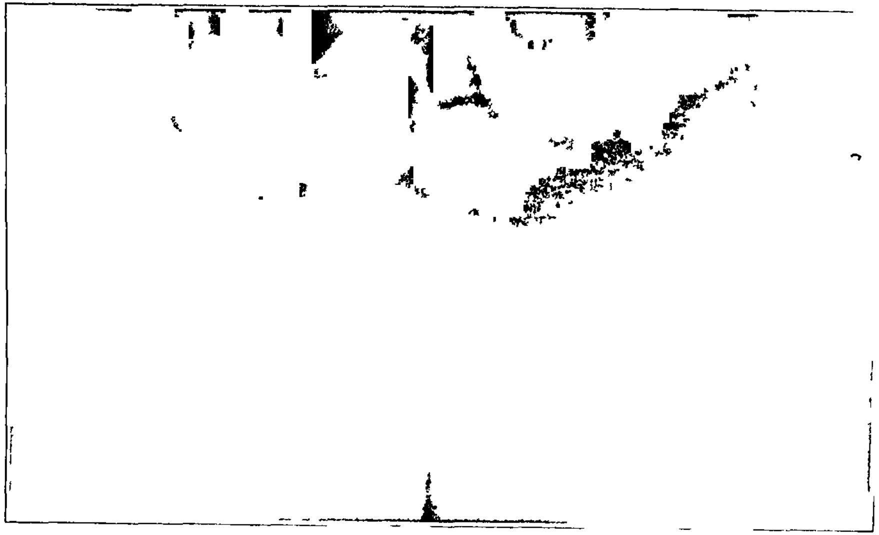

FIG. 1

December 8, 1942. Excretory urogram, made ten months before suprapubic operation, showed good function of both kidneys. The appearance of the bones of the pelvic girdle before operation was normal.

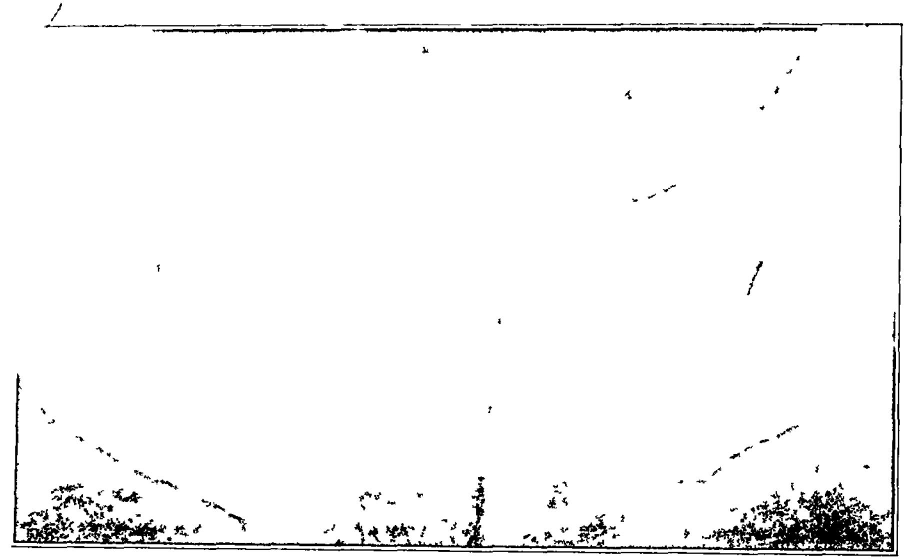

FIG. 2

December 4, 1943. Roentgenogram of the pelvis shows osteitis pubis involving the descending rami of the pubes. Film made fifty days after one-stage suprapubic prostatectomy, two days after readmission. Symptoms had been present for seven days.

FIG. 3

December 15, 1943. Roentgenogram of the pelvis shows no particular change over the previous roentgenogram, except perhaps a slight increase in the decalci-

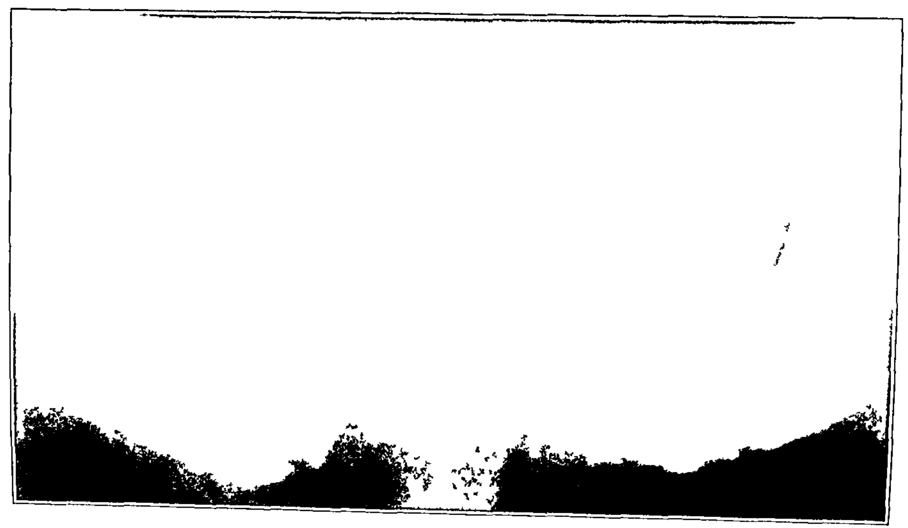

FIG. 4

January 20, 1944. Roentgenogram of the pelvis reveals good healing with redeposition of the calcium. Clinically the patient was well.

previous operation was noted. There was mild atrophy of the interossei of the hand. Flexion and extension were nearly normal, but were painful. The right wrist was equal to the left wrist in circumference. Only mild redness could be observed over the carpal navicular region.

Roentgenograms (Fig. 2-A) revealed a circular area of diminished bone density in the distal half of the carpal navicular, which was surrounded on the proximal border by an area of sclerotic bone. Careful comparison with roentgenograms made elsewhere led to the belief that this area of diminished bone density had gradually become larger and more clearly defined.

On March 24, 1945, an approach similar to that used in Case 1 was made. The carpal navicular was identified, and, by making a window in the cortex on the radial side of the bone, the surgeon encountered a definite cavity within the bone, approximately one by one centimeter in size. By the use of a small curette, this cavity was cleaned out. The bone fragments were of unusual softness for normal medullary bone, and, although the color was of the usual red, the material was easily scooped out through the window in the cortex. Inasmuch as this cavity appeared to be almost one third of the size of the entire navicular bone, *and there seemed to be danger of a pathological fracture*, many chip grafts from the distal portion of the radius were removed and inserted into the cavity. The wound was closed in the usual manner and a forearm plaster dressing was applied. In Figure 2-B, the small radial chip grafts can be seen within the navicular bone. This roentgenogram was made when the cast was removed on April 8, 1945, approximately two weeks after the operation.

The patient was followed for four months and had no pain. There was some stiffness from immobilization, but this gradually diminished. Figure 2-C is a roentgenogram taken on May 26, 1945, two months after surgery, and the previously noted osteolytic lesion is almost completely obliterated by new bone.

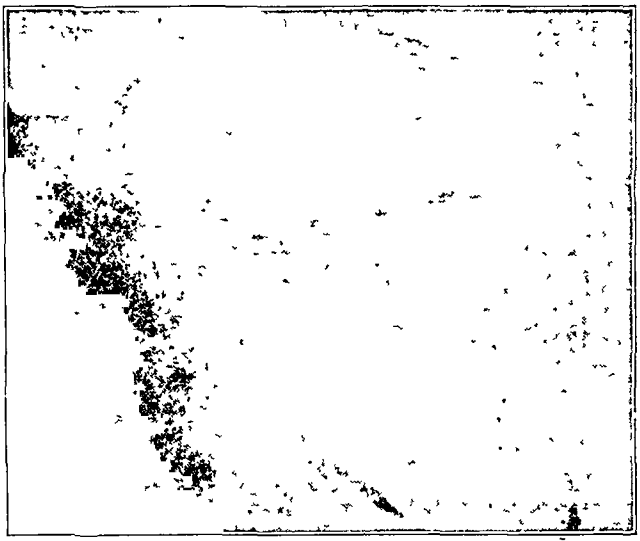

Fig. 2-A

Case 2. In the right carpal navicular, there can be seen an area of osteolysis, surrounded by an area of sclerosis. This is most evident on the proximal side.

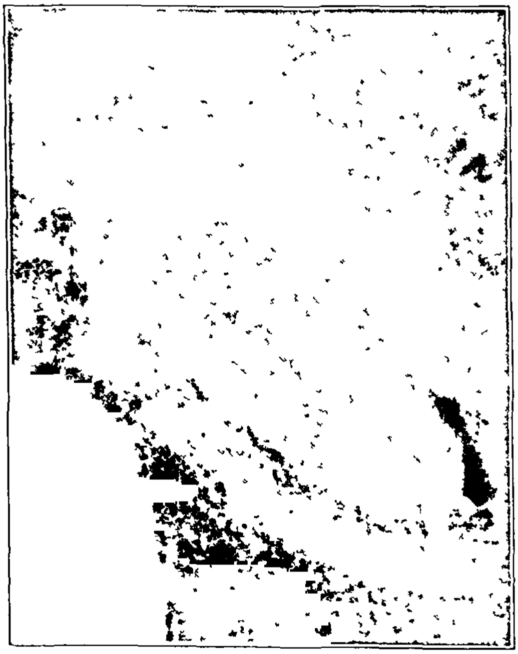

Fig. 2-B

Fig. 2-C

Fig. 2-B: Fine chip grafts from the distal portion of the radius can be seen within cavity of navicular bone.

Fig. 2-C: Two months following removal of destructive area and insertion of radial chip grafts. The diseased area is now almost completely filled in by new bone.

UNCLASSIFIED PREMATURE CESSATION OF EPIPHYSEAL GROWTH ABOUT THE KNEE JOINT

BY OTTO C. KESTLER, M.D., NEW YORK, N. Y.

Premature arrest of epiphyseal growth about the knee joint, following tuberculosis of the hip, has been described by several authors, including Gill and Zinner and Kestler. However, premature cessation of growth may occur in the epiphyseal plates about the knee joint as a result of hip disorders other than tuberculosis. Early growth arrest in the epiphyseal plates may also occur without lesions of the neighboring joints and without associated lesions being demonstrable elsewhere.[4]

Three types of unclassified cessation of epiphyseal growth about the knee have been observed by the author.

Group I

This group includes infectious hip lesions, producing early secondary growth arrest about the knee.

There is invariably a marked deformity of the knee, with the head of the fibula being prominent in every case. Occasionally there is bowing deformity. A shortening of the entire lower extremity is present, but the shortening is not to be ascribed entirely to the hip lesion, which in some cases produces only minor destruction about the hip. Detailed comparative measurements of the femur, the tibia, and the fibula indicate the actual participation of these bones in the shortening, with the exception of the fibula, which almost consistently continues to grow undisturbed.

Besides tuberculosis of the hip, including one case of bilateral tuberculosis (Fig. 1), pyogenic infection of the hip, caused by hemolytic *Staphylococcus aureus* in childhood, and one case of Still's disease (Fig. 2) have been observed by the author. The distal epiphysis of the femur and the proximal end of the tibia were almost invariably affected by a premature cessation of growth. In most of the cases of this type, marked deformity was present. There was a narrow epiphyseal plate, which was sclerotic in structure, with a star-shaped area in its center. The epiphyseal plate of the fibula was not closed, and the head of the fibula reached the level of the knee joint. Some discrepancy was also noted in the width of the tibia; and, in some cases, the fibula appeared to be hypertrophic. In cases of varus deformity, the medial portion of the tibial epiphysis appeared to be involved. Various degrees of atrophy were always present in the knee joints. The degree of atrophy about the knee joint was always more extensive in cases of tuberculosis of the hip than in cases of other etiology.

Group II

In this group are included non-infectious hip disorders causing or connected with an early cessation of epiphyseal growth about the knee on the same side.

The author observed a baby, eighteen months old, who had been treated successfully for unilateral congenital dislocation of the hip. At the age of three, however, she presented the clinical problem of shortening of the lower extremity (Fig. 3). Detailed comparative measurements, followed by roentgenograms of the knees, disclosed the growth impairment about the knee on the side of the previously dislocated hip.

Group III

This includes cases of premature cessation of epiphyseal growth about the knee, without lesions in the hip on that side and without an associated pathological process being demonstrable elsewhere.

These cases present a shortening of one of the lower extremities. The limp is usually

SUBPERIOSTEAL GIANT-CELL TUMOR

Report of a Case

BY JOHN T. HODGEN, M.D., AND CHARLES H. FRANTZ, M.D., GRAND RAPIDS, MICHIGAN

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Giant-cell tumors occurring in the shafts of long bones are unusual, and few have been reported in the literature. They fall into the so-called "subperiosteal group". The following case does not differ from those previously reported except for the questionable absence of trauma in the history.

W. B., a fifteen-year-old girl, was referred to the Orthopaedic Clinic on March 15, 1945. The patient complained of an aching pain of four months' duration in the region of the right knee. She could recall no injury to the leg. A few weeks after the onset of the initial discomfort, the symptoms became more pronounced, causing her to seek advice from her family physician. A toe-to-groin plaster cast was applied and rest was advised. Eight weeks of this regimen brought no relief. The plaster was removed and roentgenograms were made of the right tibia (Fig. 1). Because of a defect in the upper third of the tibial shaft, the patient was referred to the Clinic.

Examination revealed a healthy young girl with no abnormal findings except in the right leg. Upon inspection and palpation, the right knee joint appeared to be normal with a full range of both active and passive motion. Palpation of the upper portion of the tibial shaft, which was normal in contour, was painful on the medial aspect. This pain was most pronounced about two inches below the condyle. Urine and blood studies were normal. The blood Kahn test was negative. Roentgenograms of the right tibial shaft revealed a well-demarcated, subperiosteal area of bone destruction on the medial surface. A lateral view localized the lesion on the posterior aspect. There was no bulging of the shaft, and no periosteal reaction was present.

By the use of a pneumatic tourniquet, the tumor was explored four days after the original examination. When the involved site had been exposed, a bluish oval area one centimeter by two centimeters was visualized. The cortex was much thinned. The outer wall of the tumor was opened with a small gouge. The tissue beneath was reddish-brown in color and jelly-like in consistency. No membrane was apparent. A routine

Fig. 1

Anteroposterior and lateral roentgenograms demonstrating the lesion to be medial and posterior in the upper tibial shaft.

ETIOLOGY

Hip lesions, particularly those of an infectious nature which produce destructive changes in the joint, as a rule bring about premature cessation of the epiphyseal growth distal to the hip joint on the same extremity. The knee joint is most frequently affected. It seems, also, that the greater the destruction and the longer the lesion has been present, as in tuberculosis, the more extensive will be the growth cessation about the knee. On the other hand, the destruction does not have to be extensive to produce marked changes about the knee. Although the etiology is understood in cases of tuberculosis, pyogenic infection, and Still's disease of the hip, the cases in Groups II and III require a searching analysis.

SELECTED CASE REPORTS

CASE 1 A twelve-year-old boy was admitted to the Hospital for Joint Diseases on June 28, 1941, with a history of a fall nine weeks prior to admission. Ten days later, he had pain in the left hip and a temperature of 103 degrees. Three blood cultures were positive for *Staphylococcus aureus*. He was given sulfathiazole and placed in a plaster-of-Paris spica. His condition improved, but a week later the pain recurred and the temperature rose to 104 degrees. The following week the left hip was in a position of moderate flexion, abduction, and external rotation. The left inguinal region and the upper portion of the left thigh were markedly swollen and warm. Several tender lymph nodes were present. Traction was applied, and a blood transfusion was given. Repeated aspirations from the left hip joint produced thin purulent fluid which showed hemolytic *Staphylococcus aureus* on culture. Blood cultures were repeatedly negative. Roentgenograms of the left hip, taken on July 7, 1941, showed irregular necrosis of the superior quadrant of the capital epiphysis, with complete disappearance of the subchondral cortex and narrowing of the joint space. The patient recovered, but at the time of his last admission there was complete ankylosis of the left hip (Fig. 5-A).

The follow-up examination on February 20, 1945 (Figs. 5-B, 5-C, 5-D, and 5-E) showed that the patient was able to walk without assistance. The lumbar lordosis had increased. He had no pain. The left hip was held in neutral position as far as abduction was concerned, but it was in flexion of 150 degrees. The left lower extremity was three inches shorter than the right. There was an overgrowth of the fibula, which projected laterally on the left side with some tendency to varus deformity of the left knee. The length of the right tibia was seventeen and one-half inches; that of the left tibia was fifteen and one-half inches. The distance from the tip of the greater trochanter to the articular surface of the femur was eighteen and three-quarters inches on the right and eighteen inches on the left.

FIG. 5-A

Case 1. Showing complete bony ankylosis of the left hip.

CASE 2. This patient, with tuberculosis of the left hip, was first seen on April 29, 1939, at the age of three and one-half years, in the Out-Patient Department of the Hospital for Joint Diseases. He was treated in a convalescent home by traction, followed by the application of a brace. He was seen in the clinic on December 27, 1944, at which time he was walking with a brace and had no complaints. At the follow-up examination on March 15, 1945, he was wearing a double upright brace on the left lower extremity. The left hip was in abduction of 20 degrees and it was flexed to 155 degrees, in slight outward rotation. There was no motion in that hip. The left lower extremity was three-quarters of an inch shorter than the right; the left tibia was one-quarter of an inch shorter than the right.

FIG. 3
Photomicrograph (× 320) reveals osteoid formation. There is a good deal of hemosiderin in the fibrous tissue. (*Negative No. 99053, Army Institute of Pathology.*)

FIG. 4
Anteroposterior and lateral roentgenograms thirteen months following curettage. Healing is seen with dense cortical bone.

Fig. 6-A

Case 2. Roentgenograms of both hips.

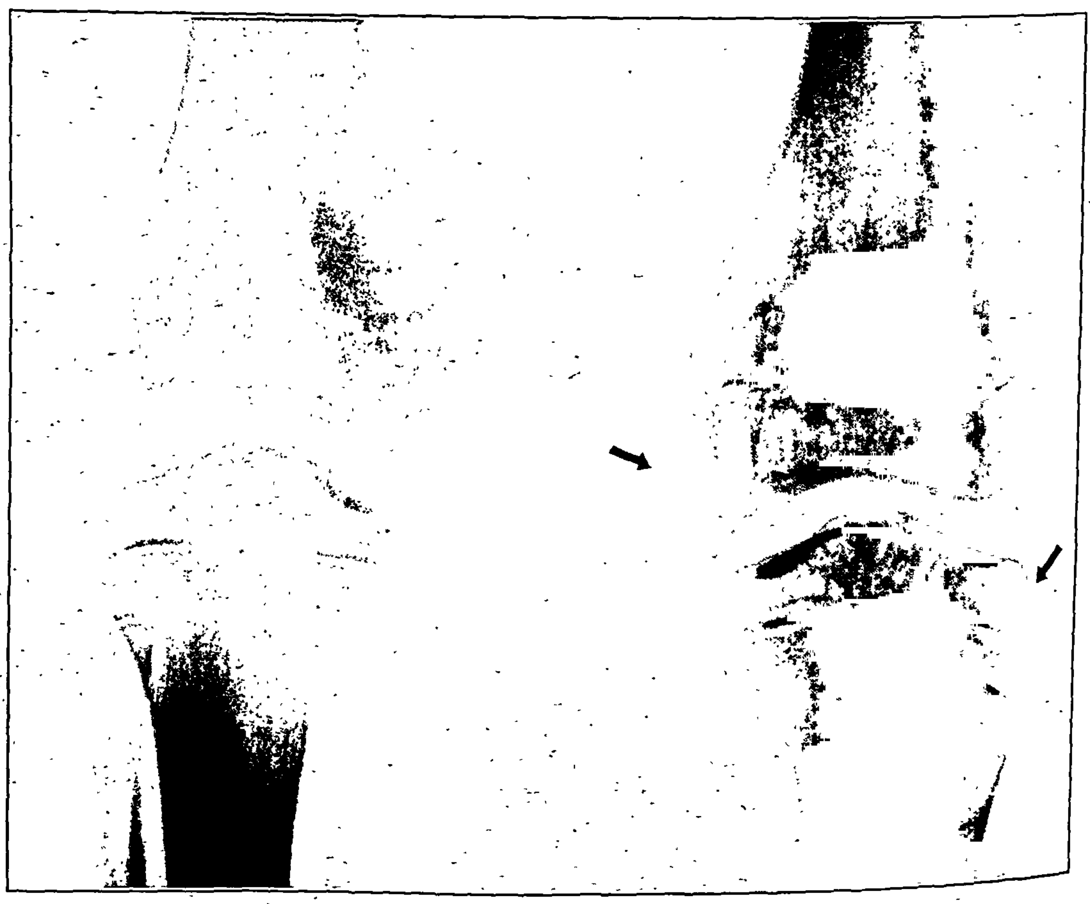

Fig. 6-B

Comparative roentgenograms of the knees. Note that the proximal end of the left tibia is narrower, the epiphyseal plate is smaller and somewhat thinner, and the head of the left fibula is on a higher level than the right. There is also marked atrophy about the left knee.

OSTEITIS PUBIS

BY NORBORNE B. POWELL, M.D., HOUSTON, TEXAS

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This relatively infrequent complication of suprapubic prostatectomy was first described by Beer in 1924, who later, in 1928, reported two cases that occurred following suprapubic bladder operations. Muschat in 1945 reported two cases of osteitis pubis and reviewed twenty-three cases in the literature, while Cohen added two more cases in 1946.

The etiology of this condition is not known. Wheeler was unable to reproduce the condition in rabbits experimentally.

Clinical Course

The onset of the condition has been given as varying from ten days to two months after operation. There is usually an insidious, dull, aching pain in the region of the symphysis pubis, which may become localized in either the right or left superior or inferior ramus. The pain may radiate to the perineal region and to the inner aspect of the thighs. Walking becomes increasingly difficult, until the patient is bedridden and suffers excruciating pain when he attempts flexion or extension of the lower extremities. Spasmodic contractions of the adductor muscles may occur on voluntary motion. The duration of the condition varies from about six weeks to as long as two years, as occurred in a patient, reported by Kretschmer and Sights, who had some pain for this length of time.

Diagnosis

The history of a recent suprapubic operation, with physical findings of pain over a localized area of the symphysis pubis, is usually enough to suggest osteitis pubis. Roentgenograms of the areas will prove the existence of the lesion after about the third week. There is a roughening or fraying of the periosteum and a moth-eaten appearance of the symphysis pubes and rami. Decalcification of the rami and inner portions of the ischia may become evident on subsequent roentgenograms. The disease is usually self-limiting with or without therapy, and in about six to ten weeks there is a recalcification and rapid reconstruction of the bones involved. Ankylosis of the symphysis pubis is the rule; otherwise, the bony structures return to normal.

There might be some tendency without roentgenograms to confuse this condition with a simple infection of the space of Retzius or of one of the perivesical spaces. Osteomyelitis of the pelvic girdle from some hematogenous infection, however, gives a different roentgenographic picture, so this condition will not be too confusing.

Bed rest not only is necessary, but the patient will wish to remain flat on his back and to move as little as possible. Body casts may be used; the relief will be complete, slight, or occasionally the condition may be made worse. Recovery is slow and tedious. Drugs — such as opiates, vitamins, and sedatives — and antibiotics may be used to alleviate the distressing symptoms.

CASE REPORT

H. S., a colored male of fifty-one years, was admitted to the Southern Pacific Hospital on September 21, 1943, with the chief complaint of intermittent hematuria of two years' duration. (The patient had been examined by a doctor eleven months before, who found slight enlargement of the prostate. The history was otherwise negative.)

Physical examination revealed essentially normal findings except for the blood pressure—systolic 160 and diastolic 94—and for a slight enlargement of the prostate.

arthritis of the right hip with considerable new-bone formation (Fig. 7-A). Roentgenograms, taken comparison, showed retardation of growth of the right pelvis, femur, and tibia. There was an early arrest growth of the lower femoral and upper tibial epiphyses. The fibula apparently was affected, also, because deformity was present about the right knee (Fig 7-B).

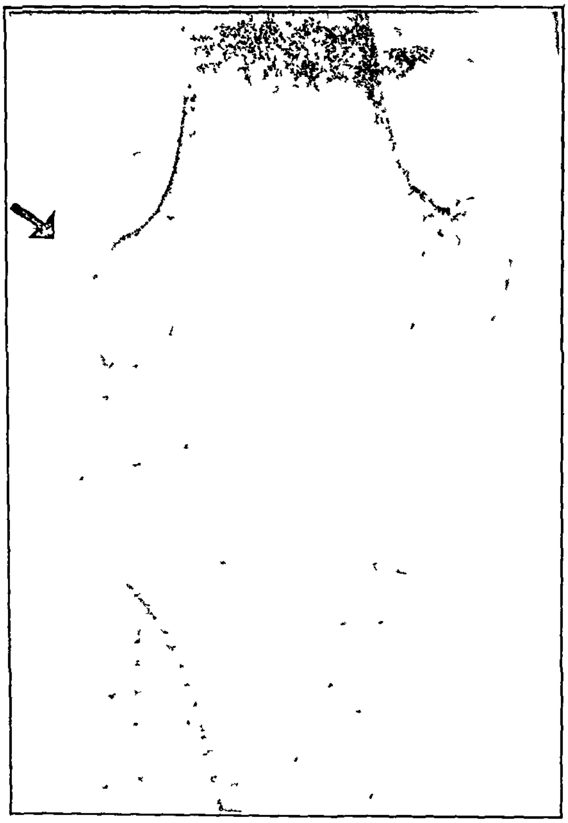

Fig. 7-B

Case 4. A male, twenty-four years old, was mitted to the Hospital for Joint Diseases on Nove ber 30, 1945, because of deformity of the left hip w extensive shortening of the left lower extremi He had had tuberculosis of the left hip since the of six years, and had received conservative treatme Upon admission, he had ankylosis of the left with a flexion deformity of 145 degrees and duction of 15 degrees. The left lower extremity one and one-quarter inches shorter than the rig The measurement from the tip of the trochanter the lateral condyle of the femur was sixteen and o half inches on the left and seventeen inches on t right. From the external condyle of the femur to t lateral malleolus was sixteen inches on the left s and sixteen and one-half inches on the right Roe genograms of the pelvis (Fig 8-A) disclosed bo ankylosis of the left hip. They also showed a d structive process, involving the acetabulum and t head of the femur. Increased density was present these areas. Roentgenograms of the knees, taken f comparison (Figs. 8-B and 8-C), showed impair growth at the epiphyses on the left side, involving t width of the femur and the tibia. Moderate atrop of the bones was also noted.

Fig. 7-B: Roentgenogram of right knee Note t impaired growth of the lower femoral and upp tibial epiphyses, with marked atrophy of these area

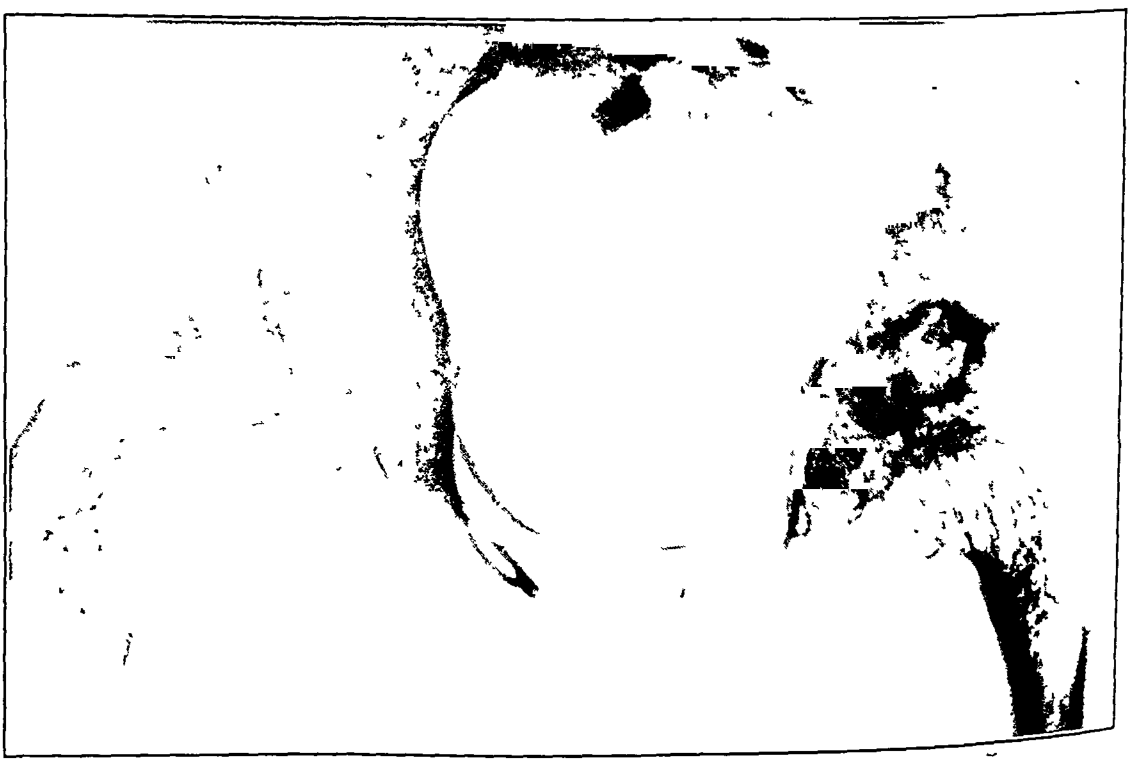

Fig. 8-A

Case 4 Roentgenogram shows bony ankylosis of left hip Although there is an area of increased density in the acetabulum and in what remains of the head of the femur, there is atrophy of the upper portion of the femur.

Blood examination showed:

Red blood cells	4,430,000
Hemoglobin	86 per cent.
White blood cells	5,900
Polymorphonuclear neutrophils	60 per cent.
Lymphocytes	40 per cent.
Non-protein nitrogen	31.5 milligrams per 100 cubic centimeters
Urea nitrogen	13 milligrams per 100 cubic centimeters

Kline and Kolmer tests were negative. The urinalysis showed a specific gravity of 1.010 with albumin four plus and red blood cells four plus. Excretory urograms showed: "Good renal function, bilateral. Flat plate of the abdomen (kidney, ureter, and bladder) essentially negative."

On the day of admission, the patient was panendoscoped under spinal anaesthesia. Bleeding was found to come from a ruptured prostatic varicosity. The prostate was slightly enlarged, and there was a definite contracture of the neck of the bladder. Transurethral prostatic resection was recommended, which was attempted on October 14, 1943. Due to failure of the instrument, a suprapubic operation was necessary. The usual mid-line suprapubic incision was made. The bladder was inflated with about 450 cubic centimeters of fluid through a urethral catheter, and was opened near the dome in the mid-line. An attempt was made to enucleate the prostate, but a complete removal of the gland was not possible, primarily because of the contracture of the neck of the bladder. A 30 cubic centimeter Foley bag catheter was left in the bladder and urethra, and a No. 34 de Pezzer catheter was also left suprapubically. Closure was with interrupted sutures of chromic catgut No. 1. The space of Retzius was drained with a rubber drain. Two grams of sulfanilamide crystals were sprinkled throughout the wound. The skin was closed with continuous sutures of black cotton. The suprapubic catheter was removed on the fifth postoperative day. On November 4, 1943, under spinal anaesthesia, ten grams of prostatic tissue was removed transurethrally, resulting in a complete prostatectomy. The postoperative course was uneventful. The patient was discharged on the fourteenth postoperative day, able to urinate freely and getting up at night only once. The suprapubic wound was healed completely. There was no recurrence of hematuria.

The patient was readmitted to the Hospital in ten days, on December 2, 1943, complaining of severe pain over the symphysis pubis and in the groin. The patient was unable to walk in an upright position and stooped because of pain in the pubic area. There was one hard, indurated lymph gland in the left inguinal region. The report of the roentgenograms (Fig. 2) of the pelvis was: "Descending rami show some irregularity of outline with some suggestion of bone destruction. Otherwise, the pelvis is negative. *Diagnosis:* Osteitis of the pubic bones."

Frequent roentgenograms showed a gradual healing process. Four weeks later, examination showed less periosteal change of the pelvic bones. There was no indication of metastasis. Roentgenograms (Fig. 4) of the pelvis and upper portion of the femur, made on January 20, 1944, showed no evidence of pathological changes of the bones. There was no definite destruction, and good healing was evident. The patient was seen by several orthopaedic consultants, who advised no special therapy except bed rest, small doses of sulfamerazine (fifteen grains three times a day for about ten days), and vitamin therapy. The patient was discharged January 22, 1944, the fifty-first day after readmission to the Hospital, completely free of all symptoms. When last seen on March 3, 1944, seven weeks after discharge, he had absolutely no complaints and considered himself cured

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change in the epiphyseal plates. In other words, the writer feels that the theory which tries to explain these changes merely on a mechanical basis is not acceptable.[2]

The periosteal vessels are the main sources of blood supply to the epiphyseal plates. These vessels form an anastomosis with the terminal branches of the nutrient artery[3]. In the writer's opinion, it is the impairment of these periosteal vessels that causes the cessation of growth. It should also be mentioned that the toxins produced by various agents of infection must play an important role. It seems evident that the cutting of the blood supply limits itself to certain areas; the appearance of the star-shaped scar in the center of the epiphyseal plate, as observed on certain roentgenograms, substantiates this assumption. The absence of pain and the presence of atrophy may be cited in support of the conception of an impaired arterial blood supply.

It is conceivable that in Group III, where no obvious changes in the neighboring joints or bones were present, a transient hip lesion might have been responsible for the cessation of growth. Various infectious diseases in childhood can cause the epiphyseal plate to cease to proliferate and to become heavily calcified. In this process, the changes are reversible: Growth is resumed, and a line of arrested growth appears as a scar in the metaphyses of the long bones, particularly in the upper portion of the tibia and the distal metaphyses of the femur[3]. In the author's opinion, however, in cases of localized joint lesions, the secondary growth arrest is irreversible. and, therefore, it produces irreversible growth changes.

Destructive pathological changes in the hip, inflammatory in nature, usually produce varying degrees of atrophy in the lower part of the femur and the upper portion of the tibia, or in both, in the same lower extremity.

There is little doubt that bone atrophy is a contributing factor and that trauma may also play a role; just how much growth arrest may be attributed to these causes is difficult to estimate. In the presence of extensive damage to the epiphyseal plates, it is strongly suspected that the coexisting pathological changes in the hip joint may be due to tuberculosis, in spite of negative laboratory findings and in the absence of biopsy examination. Although this observation has been substantiated by a number of cases, further clinical studies will be required before final conclusions can be drawn.

ADDITIONAL OBSERVATIONS

Since this article was submitted for publication, the author has had the opportunity to observe eight additional cases, bringing the total to twenty-two. The majority of the new cases belong to Group I. The fact that many of the cases in Group I were observed in various age groups, with the onset of the hip lesion at age levels varying between six months and twelve years, permits us to draw the following conclusions: Theoretically, there is a close relationship between the growth centers of the hip and the bones comprising the knee joint. Apparently, whenever the growth centers of the hip are affected by a lesion, the growth centers about the knee joint are disturbed secondarily. This distant growth control probably operates through the perivascular sympathetic chain, as a reflex.

In the cases studied, the distant changes occurred about six to eight months after the growth centers of the hip had been affected by the disease, as evidenced by the roentgenographic findings. However, two or three years elapsed before definite distant growth changes were demonstrated clinically. The peak of the distant growth changes takes place from three to six years after the onset of the hip lesion, and a remodeling takes place according to the law of functional adaptation.

The outcome of this adjustment will depend upon such factors as the original location of the growth arrest (central or eccentric in the epiphyseal plate); the duration of the acute stage of the hip disease; the nature of the lesion (tuberculous, pyogenic, et cetera); the method of treatment; early weight-bearing; and prolonged immobilization.

FIG. 1

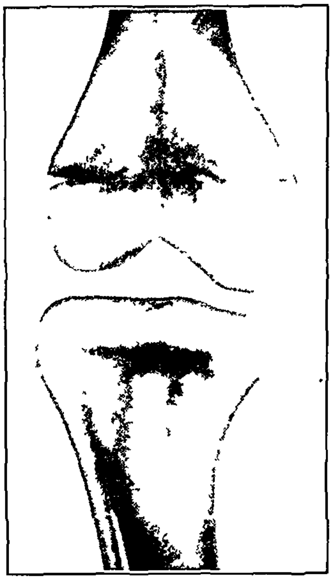

FIG. 2

Fig. 1: Fourteen-year-old boy with advanced bilateral tuberculosis of the hip. Note the extensive growth impairment in both knees, with considerable deformity.

Fig. 2: A case of Still's disease, involving several joints and both hips.

negligible, although a sixteen-year-old patient (Fig. 4) with one-half inch of shortening of the tibia had a moderate limp.

A symmetrical uniform flattening of the proximal tibial epiphyseal plate was observed in these cases, combined with abrupt widening of the proximal end of the tibia and increase of the curves of junction of the metaphyseal and epiphyseal portions of the bone. A star-shaped area of increased density in the center of the epiphyseal plate could be seen clearly. No atrophy of the bone was present in these cases. The fibula did not seem to be affected.

The earlier cases, in all three groups mentioned, were observed by the author in the Hospital for Crippled Children, Budapest.

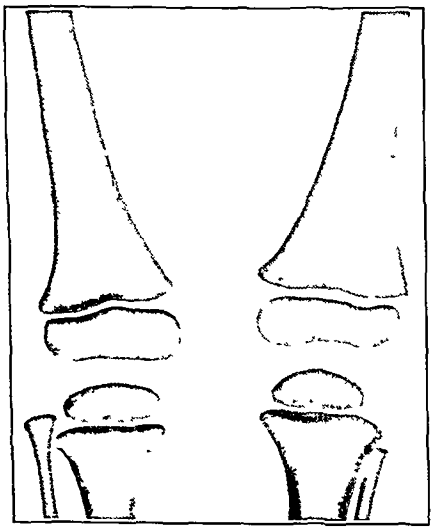

FIG. 3

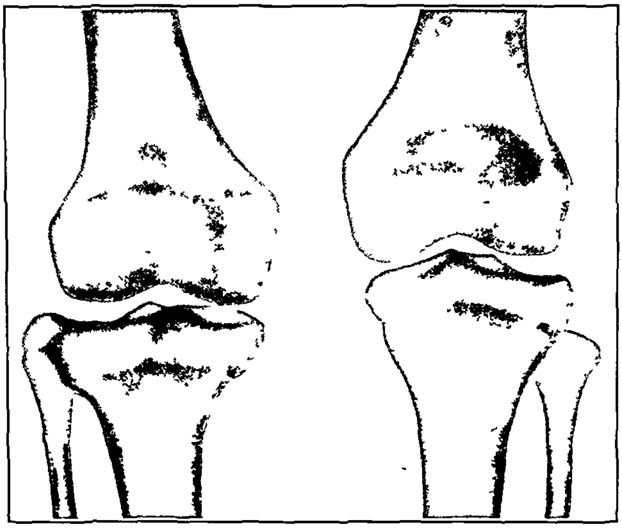

FIG. 4

Fig. 3: Lower extremities of a three-year-old girl who had a congenital dislocation of the right hip, reduced at the age of eighteen months. Note the changes in growth of the right tibia and fibula at the knee, as compared with those on the left.

Fig. 4: A case of "idiopathic dysostosis of the tibia" in a sixteen-year-old girl with one-half inch of shortening of the right tibia. Patient had no other involvement of the skeleton and no history of a hip lesion. Her only complaint was a moderate limp. Note the early arrest of the upper tibial epiphysis. The head of the fibula is level with the knee joint.

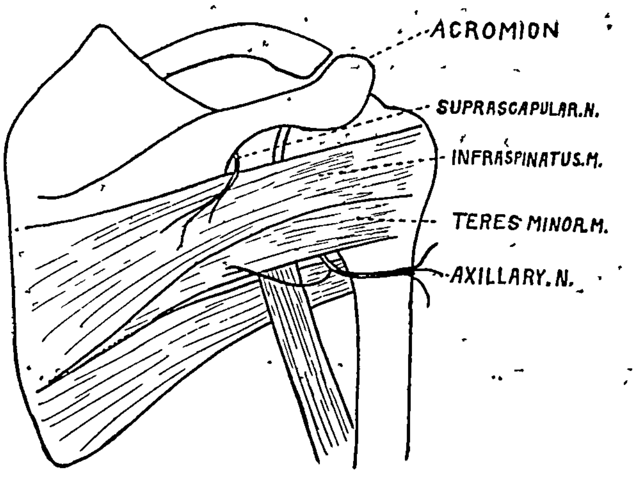

FIG. 2-A

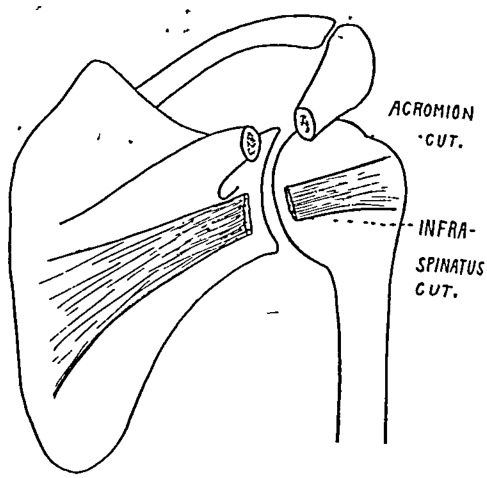

FIG 2-B

Fig. 2-A: Illustrating structures encountered in posterior approach to shoulder joint.
Fig. 2-B: The acromion has been divided two inches from its tip and the infraspinatus tendon has been divided.

shoulder is a tear of the capsule or an avulsion of the cartilaginous rim from the bony rim of the glenoid. This has been the constant finding when the joint has been exposed adequately. The logic of repairing the actual defect is clear.

In the cases to be reported, a defect in the capsule was invariably found, and Bankart's principle of capsulorrhaphy was used.

DIAGNOSIS

In three of the fifteen cases, dislocation was found to be posterior,—a more common instance than was expected. Differentiation between anterior and posterior dislocation is essential, if the defect in the capsule is to be located and repaired. The history of the mechanism of the original injury may be helpful. Anterior dislocation is caused by a force exerted on the head of the humerus from behind, either directly on the back of the shoulder or indirectly through the elbow. Posterior dislocations are caused by a force exerted on the front of the shoulder directly or through the elbow. The more common dislocations of the shoulder are caused by hyperabduction. They heal readily and do not tend to recur. When recurrence does take place, it is due to the weak inferior capsule. There may be an accurate observation of the dislocation by a medical officer, or the patient himself may be able to

FIG. 3-A

FIG. 3-B

Fig. 3-A: Vertical roentgenogram, showing posterior subluxation of head of humerus.
Fig. 3-B: Postoperative roentgenogram, showing acromion held in position by Kirschner wire.

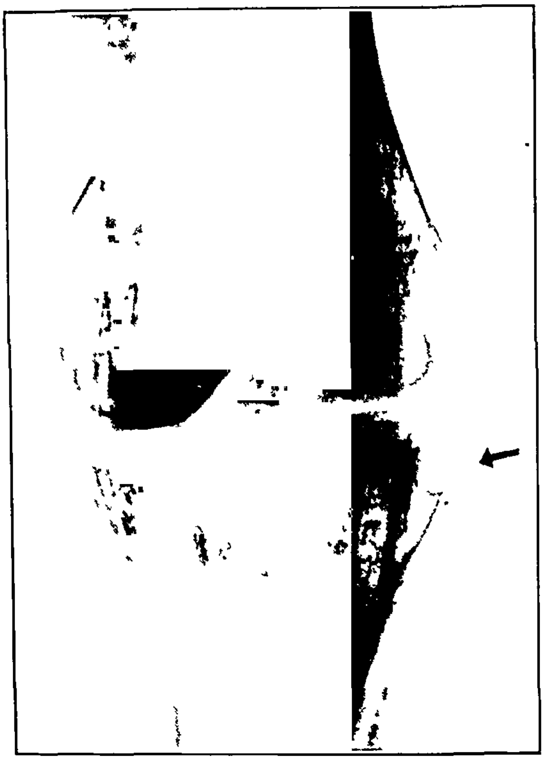

FIG. 5-B

FIG 5-C

Fig 5-B: Anteroposterior view of the left knee. Note the changes of the upper tibial epiphysis, as compared with the right knee (Fig 5-D). There is marked atrophy of the femur and tibia.
Fig. 5-C: Lateral view of left knee Shows marked atrophy

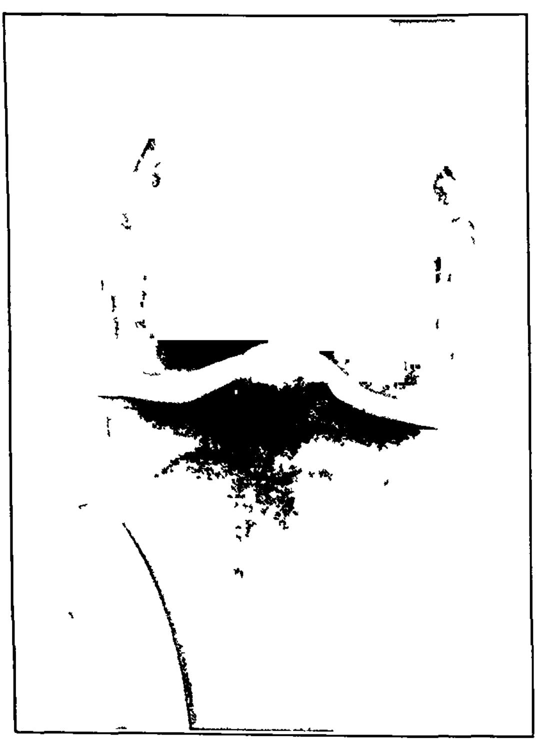

FIG 5-D
Anteroposterior view of right knee.

FIG 5-E
Lateral view of right knee

its tip and rotated laterally and forward, giving free access to the defect in the capsule (Figs. 2-A and 2-B). If the capsule forms a sac into which the head of the humerus is dislocated, it is opened and plicated snugly. If the cartilaginous rim of the glenoid has been avulsed, as in the anterior dislocation, it is excised and the capsule is sutured to the freshened rim of the glenoid with silk sutures. The sutures are passed through holes drilled in the bony rim, as in the operation for anterior dislocations.

At closure, the infraspinatus tendon is sutured, being plicated if it is redundant. The fracture of the acromion is reduced and fixed by a Kirschner wire inserted longitudinally. The wire is sharpened at both ends, inserted from the fracture site into the lateral fragment first, and then drilled back into the medial fragment (Fig. 3-B).

RESULTS

Fifteen patients—twelve with anterior dislocation and three with posterior dislocation—have undergone operation. All dislocations were originally traumatic with multiple recurrences on such slight provocation as combing hair, putting on an overcoat, swimming, or turning in sleep.

There have been no postoperative recurrences to date in a follow-up period varying from a minimum of seven months to a maximum of eighteen months. All of these patients have been using their shoulders actively without restraint. Thirteen of the fifteen patients are at work. Most of them are engaged in strenuous occupations, such as those of commercial fisherman, hard-rock miner, physical-training instructor, professional hockey player, farmer, and logger.

None of the patients have had serious limitation of motion. As a rule, there has been 10 to 15 degrees' limitation of external rotation and abduction in the anterior dislocation (Figs. 4-B and 4-C), and 10 to 15 degrees' limitation of internal rotation and abduction in the posterior dislocations (Figs. 3-D and 3-E).

CONCLUSIONS

1. Differentiation between anterior and posterior dislocation is essential.
2. Repair of the actual defect in the capsule as described by Bankart is the logical, most effective, and least disabling method of treatment for posterior dislocation as well as anterior.

NOTE: The illustrations were prepared in the Photographic Department of the Shaughnessy Hospital

The last roentgenogram of the left hip, taken on December 7, 1944, showed a fairly old destructive, infectious tuberculous arthritis, with some sequestra. The left fibula was prominent, and there was a tendency to moderate varus position of the proximal end of the left tibia. Roentgenograms of the knees, taken for comparison, disclosed extensive atrophy of the distal end of the femur and of the proximal end of the tibia (Fig. 6-B). There was only a moderate growth arrest of the proximal femoral epiphysis, but the entire tibia was narrower than the right one.

CASE 3. A male, thirty-two years old, was admitted to the Hospital for Joint Diseases on August 27, 1945, because of pain and deformity of the right hip and considerable shortening of the right lower extremity. He had had an injury to the right hip at the age of ten. After that, he was in bed for one and one-half years. Eight years after the injury, a piece of bone was extruded from the right groin, followed by drainage of pus. This condition healed after two years, but the patient had had a limp which had grown progressively worse. On physical examination, the right hip was found to be in flexion of 150 degrees and adduction of 25 degrees; and it was ankylosed clinically. The right half of the pelvis and entire lower extremity, including the femur and the tibia, were found to be underdeveloped. The right lower extremity was three and three-quarters inches shorter than the left. A diagnosis was made of infectious arthritis of the right hip with ankylosis. Marked genu recurvatum was present on the right. Roentgenograms showed underdevelopment of the right pelvis and femur. The hip joint was deformed. The shape of the femoral head had changed completely, and most of it was absent. There was increased density of the acetabulum, and of the head and neck of the femur. Osteoporosis of the right pelvis and femur was seen. The roentgenographic diagnosis was advanced infectious

FIG. 7-A
Case 3. Roentgenogram of pelvis shows underdevelopment on the right.

FIG. 1

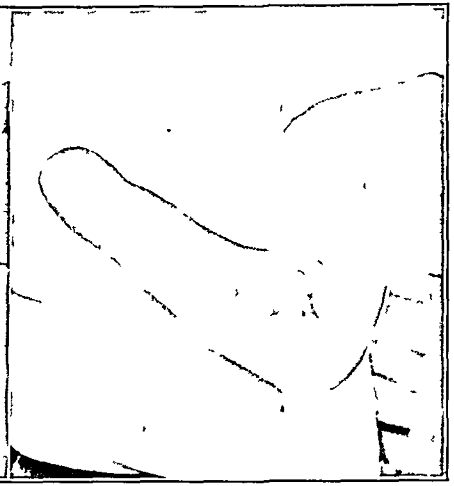

FIG. 2

Fig. 1: Stump in flexion and external rotation.
Fig. 2: Stump in adduction and internal rotation.

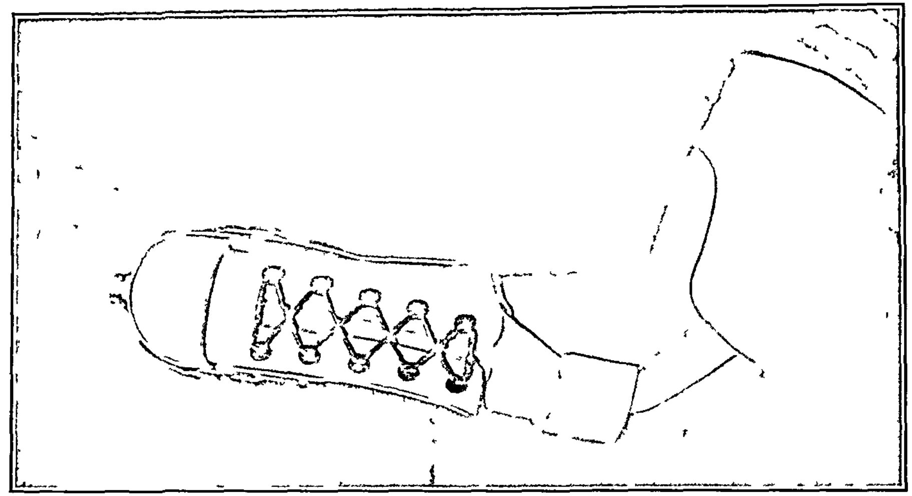

FIG. 4

Arm cuff, webbing sling, and the polymatic joints between the bucket and forearm cuff have been assembled.

FIG. 3

Bucket and forearm cuff

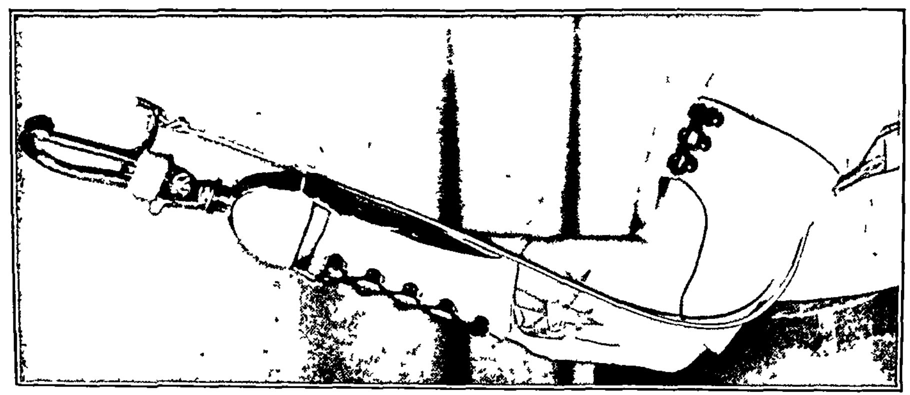

FIG. 5

Completed prosthesis, with hook and cable lanyard attached.

DISCUSSION

Although a variety of factors should be considered when early cessation of growth occurs about the knee, either from a neighboring joint lesion or from apparently unknown cause, the author believes that the main factor producing these changes is the impaired blood supply to the growth centers. This impaired blood supply is caused by indirect action, affecting the arteries of the epiphyses; a reflex action explains the distant

Fig. 8-B

Comparative roentgenograms of the knees. Note the underdevelopment of the left knee as compared with the right, and the extensive atrophy of the bones.

Fig. 8-C

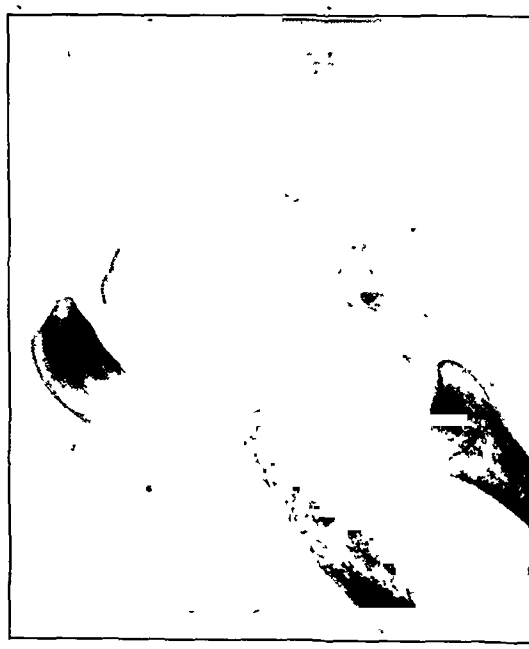

Fig. 8-D

Lateral roentgenograms of both knees (Fig. 8-C, left; Fig. 8-D, right). The marked atrophy is readily seen in these comparative views.

hand is added over the distal end of the bucket (Figs. 3 and 4). A leather cuff for the upper arm is fashioned, and the prosthesis is then assembled and fitted on the patient. A sling of webbing is made around the elbow. The hook and the hand are fitted, and the cable lanyard and sling to the opposite shoulder are aligned and adjusted (Fig. 5). This mechanism is used to operate the hook or hand. The weight of the prosthesis is about one pound, without the hook or hand being attached.

The patient then takes the routine course of training in the use of an arm prosthesis, and must pass a satisfactory achievement test, including automobile driving.

The range of motion of the amputation stump, when fitted with this type of prosthesis, is not so complete as for the normal wrist, but from 60 to 80 per cent. of the normal wrist motion is restored to the amputee. Pronation and supination approach normal (Fig 6) Flexion and extension are very good (Fig. 7). Circumduction is good. Adduction and abduction are limited, but can be achieved by a manual quarter turn of the artificial hand on its coupling. Power is excellent, and straight lifting is adequate. Normal length is maintained. Performance with this prosthesis, fitted with a mechanical hook, is excellent; and the amputee has better utilization with the hook than a forearm amputee has with a standard prosthesis. This is demonstrated by the higher grades recorded in performance of the achievement test by an individual who has had this type of amputation. By using his remaining normal wrist motion, the amputee can achieve with his hook smoother, faster, and better neuromuscular coordination, closely simulating natural motion

By making alterations in the standard artificial hands which are available, one of these can be attached to the prosthesis by removal of the wrist section, in order to make a receptacle for the bucket. The utility of the artificial hand is still limited to the function available in it. A cosmetic covering for the hand is provided, and it serves fairly well to hide the amputee's deformity (Figs. 8 and 9).

CONCLUSIONS

1. A new type of prosthesis has been developed, which proves satisfactory for carpometacarpal disarticulations.
2. With this type of amputation, most of the normal function at the wrist is retained, and it can be used in working the prosthesis.
3. The stump, without a prosthesis, is more useful than a forearm stump.
4. As much of the upper extremity as possible should be saved during an amputation

Distant changes should be watched for during the management of hip lesions, and they should be considered whenever procedures are planned for the equalization of limb length.

NOTE: Because of wartime conditions in Budapest, the original roentgenograms for Figures 1, 2, 3, and 4 were lost. When communications were re-established, the author was told that all the films in the hospital had been used to fill the gaps in the windows in order to protect the patients from the elements, since no glass could be obtained.

A paper containing these illustrations had previously been published privately in Europe, and the prints shown here were reproduced from photographs of these illustrations. The author regrets that the results have not been more satisfactory.

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DIAGNOSIS AND TREATMENT OF RECURRENT DISLOCATION OF THE SHOULDER

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Bankart's method of repair for recurrent dislocation of the shoulder has become widely accepted. It is generally agreed that the pathology of recurrent dislocation of the

FIG. 1-A

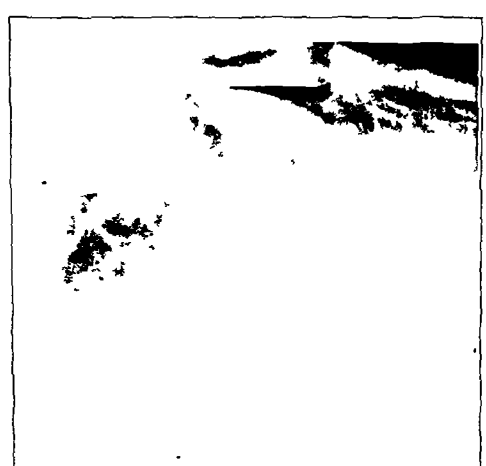

FIG. 1-B

Fig. 1-A: Preoperative roentgenogram, showing irregularity of anterior inferior rim of glenoid cavity, which resulted from anterior dislocations.

Fig. 1-B: Illustrating hatchet-shaped deformity of the head of the humerus in the case of long-standing, recurrent dislocation.

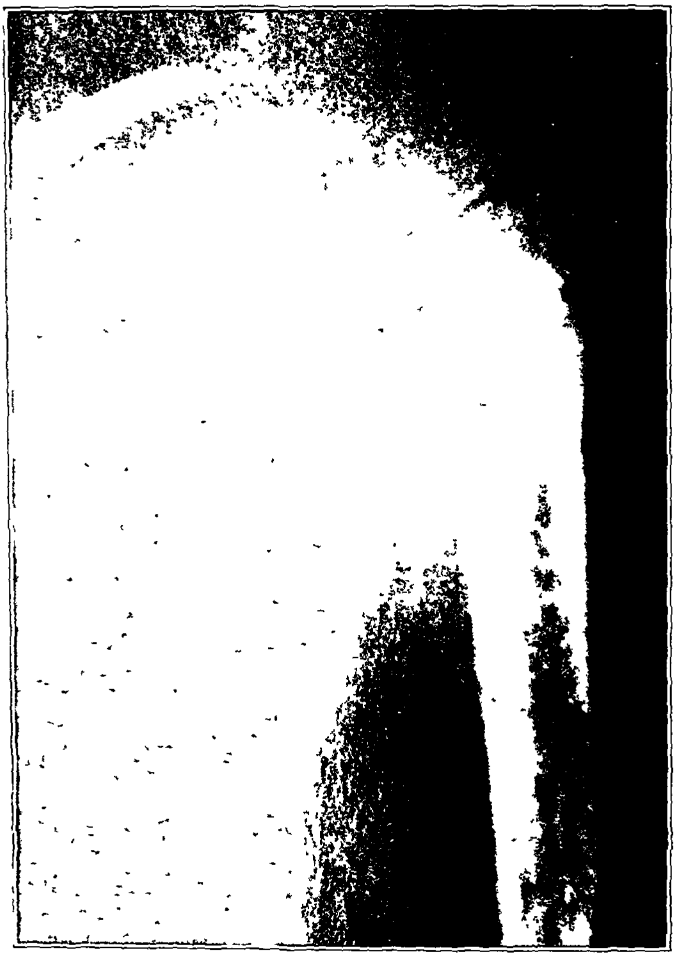

FIG. 2
Changes in the upper portion of the left humerus were similar to those in right elbow, but to a lesser degree.

CASE REPORT

A negro boy of six was admitted to the Orthopaedic Service of the University Hospital because of a swelling about the right elbow. The history, as given by the mother, was th the child had fallen and injured his right arı one month prior to his admission to th Hospital. Soon after the injury, the arm wa placed in a cast by the family doctor. Shortl after this, the elbow became swollen; feve developed; and it was necessary to remove th cast. The swelling of the elbow continued, an it increased rapidly in size over a period of fou weeks prior to admission.

The mother stated that, in October 194 she had noticed that the patient's left eye wa beginning to turn white, and that, in December 1944, it was removed and replaced with a artificial eye. This operation had been per formed in a hospital in another state, and a pathological report from that hospital state that the eye had been removed because of a retinoblastoma.

Physical examination revealed that the child had a firm, tender, fusiform swelling o the lower third of the humerus, about six centimeters in diameter, which, upon palpation, felt definitely warmer than the rest of the extremity. The motion of the elbow was severely restricted and painful. The lymph nodes were enlarged in both axillae; those on the right side were two centimeters in diameter, while those on the left were somewhat smaller. The epitrochlear nodes at the right elbow were also enlarged to a diameter of two centimeters. The only other significant finding was the presence of an artificial eye on the left. The patient's temperature ranged between 100 degrees and 101 degrees by rectum throughout his hospital stay.

Blood examination showed:

Red blood cells	2,130,000
Hemoglobin	5 grams per 100 cubic centimeters
White blood cells	7,400
Polymorphonuclears	59 per cent.
Lymphocytes	31 per cent.
Eosinophils	3 per cent.
Basophils	2 per cent.
Stab forms	5 per cent.

There were nine nucleated red blood cells per 100 white cells counted; and moderate hyperchromia, anisocytosis, poikilocytosis, and polychromatophilia were present. Coagulation time was five minutes, and the bleeding time was nine minutes. The blood Kline test was negative.

Chemical analysis of the blood revealed:

Non-protein nitrogen	50 milligrams per 100 cubic centimeters
Inorganic phosphorus	4.35 milligrams per 100 cubic centimeters
Alkaline phosphatase	4.2 Bodansky units

The urine contained no albumin or sugar.

Roentgenographic examination showed mild atrophy of the lower end of the humerus, swelling of the soft tissues, vertical striations of the periosteum, and irregular areas of bone absorption. New-bone formation was present about the lower three inches of the right humerus (Fig. 1-B). These roentgenographic findings were considered, at the time, to be typical of osteogenic sarcoma. During the examination of other parts of the body, it was found that the upper portion of the left humerus also showed the same type of periosteal new-bone formation with vertical periosteal striations (Fig. 2). Roentgenograms of the skull showed an irregular

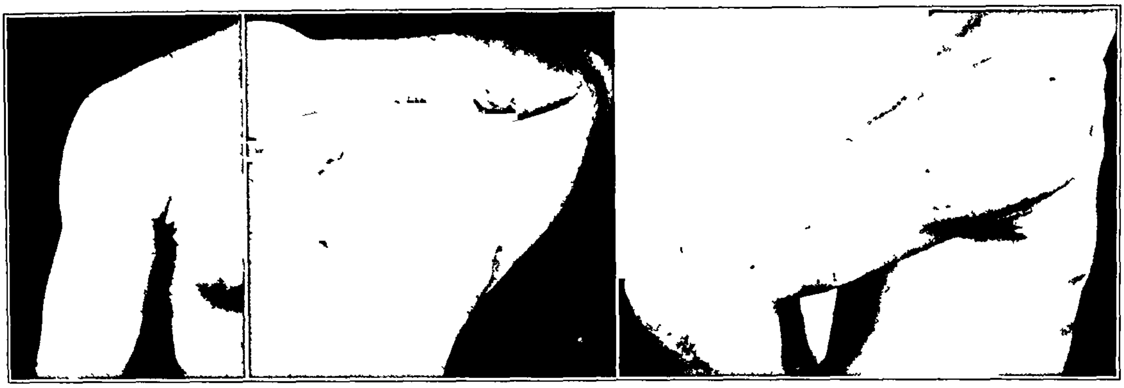

Fig. 3-C Fig. 3-D Fig. 3-E

Fig. 3-C: Incision of a previous unsuccessful Nicola operation for a posterior dislocation.
Figs 3-D and 3-E: Illustrating movement of the shoulder three months after posterior capsulorrhaphy.

describe the deformity clearly. Occasionally, the patient may be able and willing to produce the dislocation voluntarily, especially if it is a posterior dislocation. Then the diagnosis is clear. A vertical roentgenogram may be taken for a visual record (Fig. 3-A). Anterior dislocations can rarely be produced at will by the patient. However, roentgenograms may show a defect in the anterior rim of the glenoid or a hatchet-shaped deformity of the head of the humerus. These are the results of repeated dislocations (Figs. 1-A and 1-B). Occasionally, it may be necessary to produce the dislocation again under anaesthesia in order to determine the type with certainty.

OPERATIVE TECHNIQUE

Anterior Dislocation

The operation used to correct anterior dislocation in these cases is almost identical to that described by Bankart. The defect is repaired by suturing the capsule to the freshened rim of the glenoid with three or four interrupted sutures of heavy silk. These sutures are passed through holes drilled in the bony rim. A shoemaker's awl, or a similar instrument, can be used for this purpose.

Posterior Dislocation

The approach to the joint for the repair of the posterior dislocation was originated by one of the authors (R. R.). With an osteotome, the acromion is divided two inches from

Fig. 4-A Fig. 4-B Fig. 4-C

Showing range of movement four months after repair of a posterior dislocation.

plicity of lesions, combined with a normal alkaline-phosphatase determination, would deter one from making a diagnosis of ostoeogenic sarcoma. The literature reveals that little has been written about the appearance of the metastases of a retinoblastoma to the long bones.

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CALCAREOUS DEPOSITS IN SOFT TISSUES ABOUT THE PROXIMAL INTERPHALANGEAL JOINT OF THE INDEX FINGER

REPORT OF A CASE

BY ANTHONY F. DEPALMA, M.D., PHILADELPHIA, PENNSYLVANIA

From the Department of Orthopaedics, Jefferson Medical College, Philadelphia

The report of this case is prompted by findings in the patient's history which may shed some light on the etiological factors responsible for the presumably unwarranted deposition of calcium about joints. The case recently reported by Vasko[1] is of interest; in fact, the two cases had very similar clinical features and responded to practically the same treatment.

G. T., a man, aged forty-nine, complained chiefly of pain and swelling of the left index finger. The onset was gradual; during the month of March 1946, he had noticed some swelling of the proximal interphalangeal joint of the left index finger. The swelling was accompanied by considerable pain, and motion of the affected joint was restricted. There was no history of injury to the part. The pain was most intense at night, and was aggravated by the slightest motion. During the previous four months, the symptoms had not abated, but rather had become progressively worse.

The past history revealed that, in November 1942, the patient had had a "septic sore throat". This was followed by pain in all the joints of the hands and feet; the spine, knees, ankles, shoulders, and elbows were also affected. The patient had been in the hospital from January 13, 1943, to March 17, 1943. At that time a tonsillectomy had been performed, and he had been treated by autogenous vaccines, the sulfonamides, and blood transfusions. The patient had made a good recovery, and only occasionally (about twice a year) had he had some mild joint manifestations, as pain and stiffness of the small joints of the hands and feet. He had received vaccine therapy for one year. He stated that at no time had his joints been swollen.

The patient was allergic to several kinds of food and pollens. He was under constant treatment for his various sensitivities. He stated definitely that at the time of the onset of the present illness he had no allergic manifestations.

A PROSTHESIS FOR CARPOMETACARPAL AMPUTATIONS

BY COMMANDER THOMAS JOHN CANTY

Medical Corps, United States Navy

From the Amputation Center of the Mare Island Naval Hospital, Mare Island, California

Since the establishment of Army and Navy Amputation Centers during World War II, the number of possible levels of election for arm amputations has increased. This is due to the increase in the surgeon's knowledge, as a result of a closer relationship between amputation surgery, limb-fitting, artificial limbs, and prosthesis training.

In war casualties, the level of the amputation has generally been determined by the enemy fire. Since the development of the Fitch elbow control, a person with either a shoulder disarticulation or a very short upper-arm stump can use a prosthesis. The Meyer polymatic-gainer elbow hinge has provided the short below-the-elbow stump with a functional prosthesis. A suitable prosthesis is now being made for wrist disarticulations and carpometacarpal amputations. Thus, the time-honored principle of "save as much of the hand as possible" now applies to the entire upper extremity.

In the past, with injuries and destruction of tissue through the carpometacarpal zone, surgeons have been required to perform amputations through the lower third of the forearm. Wrist disarticulation has been objectionable in this type of case, because of the difficulty of fitting a prosthesis. When a standard below-the-elbow prosthesis was fitted to a disarticulated wrist, the total length of the prosthesis necessarily exceeded the normal length of the human extremity. Pronation, supination, flexion, extension, adduction, abduction, and circumduction were also lost.

At the various Army Amputation Centers, thirty-seven wrist disarticulations have been performed. Most Army surgeons favor wrist disarticulation. The principal difficulty has been the development of a suitable prosthesis. Northrop Aircraft, Inc., Prosthetic Division, under the auspices and contract of the Committee of Artificial Limbs of the National Research Council, has developed a suitable prosthesis for use in cases of wrist disarticulation. This device allows excellent pronation and supination, but the remaining motion of the wrist is lost. The length of the prosthesis is similar to that of the normal extremity.

At the Amputation Center of the Mare Island Naval Hospital, disarticulations at the carpometacarpal joints have been made in cases in which there had been loss of tissue distal to that zone. The amputated stump retains a high degree of normal wrist motion. Without a prosthesis, the amputee can accomplish a great deal with his stump, because of its longer length, power, and motion (Figs. 1 and 2).

It is desirable to fashion the stump in a somewhat bulbous shape, with a slight degree of flatness in the postero-anterior aspect. This helps to retain the stump in the bucket. The flexor and extensor muscles which have their insertions in the distal ends of the metacarpals (extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, flexor carpi radialis, and flexor carpi ulnaris) are sutured together over the carpal bones. This helps the power of flexion and extension of the stump. It is essential to utilize the palmar skin for the stump covering, in order to provide durable skin over the end of the stump.

After the surgical wound has healed, intensive exercise, passive and active, with increasing resistance, is prescribed. Shrinking of the stump is accomplished with an elastic bandage. A plaster reproduction of the stump and forearm is made, and a light plastic bucket and forearm cuff are formed over the plaster reproduction. Polymatic joints are set between the bucket and the cuff at the normal wrist axis, and the coupling for the hook or

CRYPTOCOCCUS NEOFORMANS INFECTION (TORULOSIS) OF BONE

Report of a Case

BY CLARAN H. JESSE, M.D., LOS ANGELES, CALIFORNIA

From the Orthopaedic Service, Los Angeles County General Hospital, Los Angeles

The first article on Torula infection in man, involving the central nervous system, was written by Zenker in 1861. Since that time, there have been numerous reports of the involvement of other tissues, but it is believed that this is the first report of bone torulosis

A Caucasian male, twenty-four years old, came to the Hospital on April 12, 1945, stating that his right hip occasionally "came out of place". He was referred to the Orthopaedic Clinic.

The patient stated that pain had suddenly appeared in the right "hip" two weeks before, and he localized it by pointing to the greater trochanter. The pain was described as a "sore feeling", and at times it awakened him at night. He had had several osteopathic treatments, but the pain had not been relieved.

The patient had had the usual childhood diseases, with a questionable history of smallpox. Attacks of epilepsy began at the age of four and continued to the time of examination. He had been treated since January 26, 1945, by members of the Eye Service for a corneal ulcer of the right eye. Urinalysis at that time was normal, and tests with tuberculin No. 1 and No. 3 were negative. A coccidioidin skin test and a Wassermann reaction were also negative. The report of the chest film, taken on January 29, 1945, was as follows: "Hazy and patchy infiltration, most marked in the right lung field and accentuated in the right apex, consistent with pulmonary tuberculosis. The possibility of infection with Coccidioides cannot definitely be ruled out." A second chest film, on March 3, was reported as unchanged. The patient had no clinical chest symptoms or complaints at any time.

Physical examination, on April 12, 1945, disclosed a normal-appearing right lower extremity. The patient walked with a right-sided limp, and thigh flexion was limited to 60 degrees because of pain. Anteroposterior and lateral roentgenograms of the hip were taken, and showed a cyst about two centimeters in diameter in the right inferior pubic ramus (Fig. 1). The hip was normal.

The patient returned on April 24, with the same complaints as on his initial visit. He stated that, as he was walking in the hall, he felt a "snap" in his "hip" and then had more pain. Because of the possibility that a pathological fracture had occurred, a flat plate of the pelvis was ordered immediately. Examination of the wet film showed that the "cyst" was much larger than it had been two weeks previously, and that the lower cortex of the right inferior pubic ramus showed more destruction. The patient was then admitted to the Hospital for further study. Another physical examination showed no additional findings.

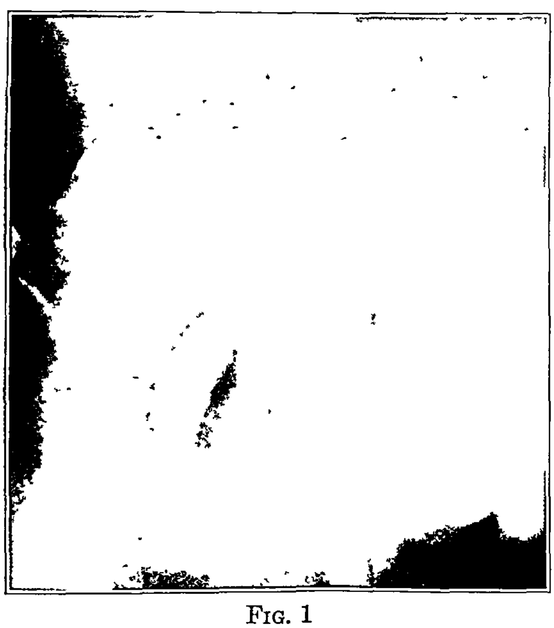

Fig. 1

Anteroposterior view of the right hip, taken April 12, 1945, shows the lesion. The cystic area in the inferior pubic ramus can be noted readily.

The following laboratory studies were then made: On May 1, a coccidioidin skin test was negative. The next day, a complement-fixation test for Coccidioides was negative, as was a spinal Wassermann. Roentgenograms of the pelvis, taken on May 12, showed the lesion to be enlarged and the upper cortex of the inferior ramus to be invaded (Fig. 2). The blood count was within normal limits. Roentgenograms of the skull, taken on May 14, showed no bony abnormality. Determinations of blood calcium, phosphorus, and phosphatase were within normal limits.

On May 24, the area was explored, and a specimen was taken for biopsy examination. The area was cystic and contained a reddish-yellow cheesy material, with a little yellowish fluid. A sample of this material was sent to the laboratory for routine smear and culture, and also for examination for acid-fast bacteria. The patient had a low-grade fever before surgery and for several days following it, but his temperature then returned to normal. The smear showed a few polymorphonuclear leukocytes; no pathological organisms were present. The culture showed no growth in forty-eight hours.

The microscopic pathological findings were:

"*Curettings from Bone:* Section is that of granulation

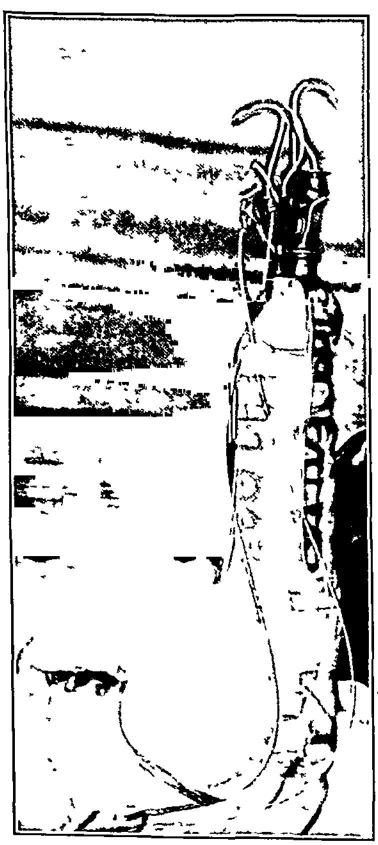

FIG. 6
Pronation and supination possible with hook.

FIG. 7
Flexion and extension possible with hook.

FIG. 8
Pronation and supination possible with the hand.

FIG. 9
Flexion and extension possible with the hand.

AN INSTRUMENT FOR USE IN THE BANKART OPERATION FOR RECURRENT DISLOCATION OF THE SHOULDER

BY MAJOR GEORGE I. REISS

Medical Corps, Army of the United States

It is generally agreed that the Bankart type of repair is the operation of choice in the treatment of recurrent dislocation of the shoulder. The most arduous and time-consuming step in this procedure is the placing of sutures through the osseous margin of the glenoid cavity. In the past, in our experience, the average time required to place these sutures usually has been from one-half to three-quarters of an hour. By using the "suture carrier" described here, the operation can be shortened to at least half the time.

There is a separate suture carrier for each shoulder, shaped in such a manner that the surgeon has good vision of the operative field while placing the suture. Instead of two mattress sutures, suggested by Bankart, four interrupted sutures are placed. The capsule of the shoulder joint is exposed by reflecting distally the common origin of the short head of the biceps, the coracobrachialis, and the pectoralis minor, and by dividing the subscapularis

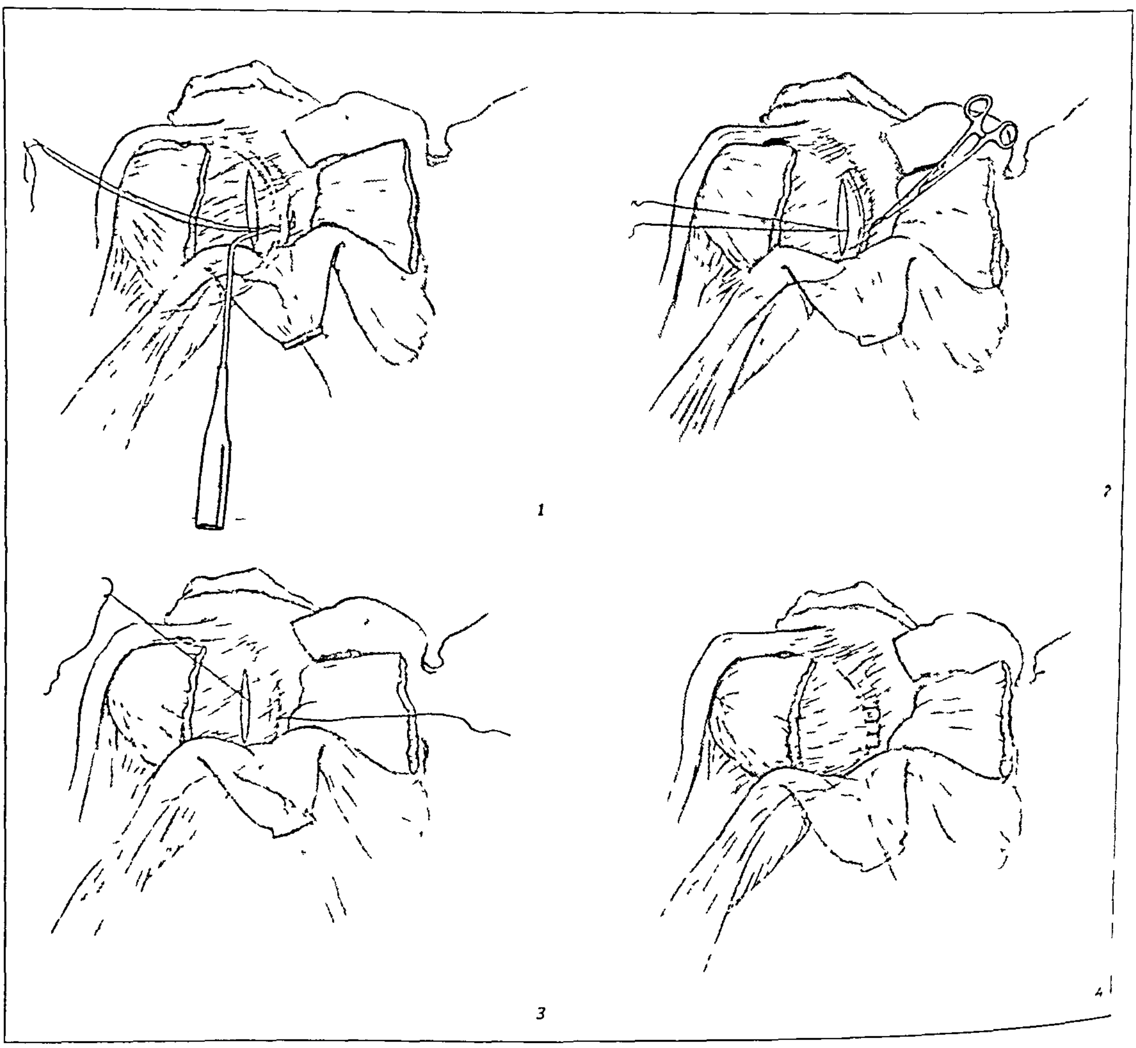

FIG. 1
Drawings show how the hole is drilled and the suture is applied.

ROENTGENOGRAPHIC FEATURES OF METASTASES OF A RETINOBLASTOMA TO THE LONG BONES

Report of a Case

BY RALPH E. ROWEN, M.D., LITTLE ROCK, ARKANSAS

From the Orthopaedic Division of the Department of Surgery, University of Arkansas, School of Medicine, Little Rock

While cases of retinoblastoma reported in the literature are not uncommon, a study of the roentgenographic features produced by their long-bone metastases has not been emphasized. The origin of this tumor has not been absolutely established, but it is quite certain that it arises from the posterior portion of the retina and consists of small, closely packed, round or polygonal cells with large, darkly stained nuclei and scanty cytoplasm. The "rosettes", which are frequently present, are believed to be derived from the early rods and cones, although this is not absolutely certain. Broders emphasizes the fact that the tumor cells arise from the regenerative layers of the epithelium, where the cells have the capacity to reproduce. Parkhill and Benedict believe that, although the ganglion cells of the retina are too highly differentiated to become malignant, the supporting or glial cells do become anaplastic and form malignant tumors. It is their opinion that these cells no longer have the form of glial cells, but that they resemble in appearance the undifferentiated cells seen in the highly malignant tumors of the adrenal glands, known as neuroblastomata.

A case of retinoblastoma of the right eye, with metastases to the skull and long bones, was studied recently. Since this case presented interesting lesions by roentgenogram, it is being reported.

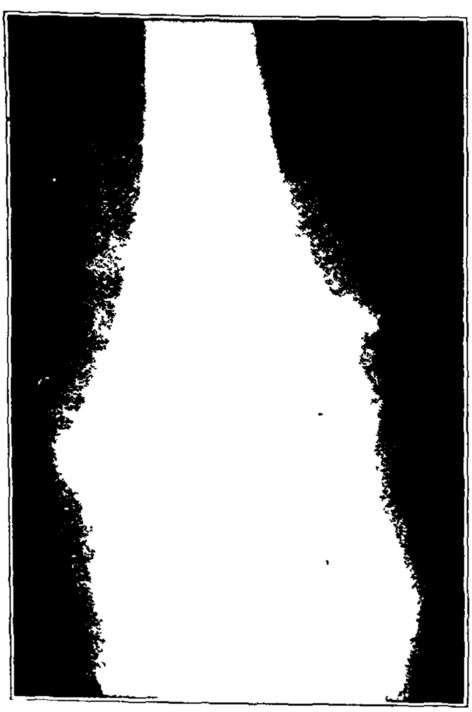

Fig. 1-A

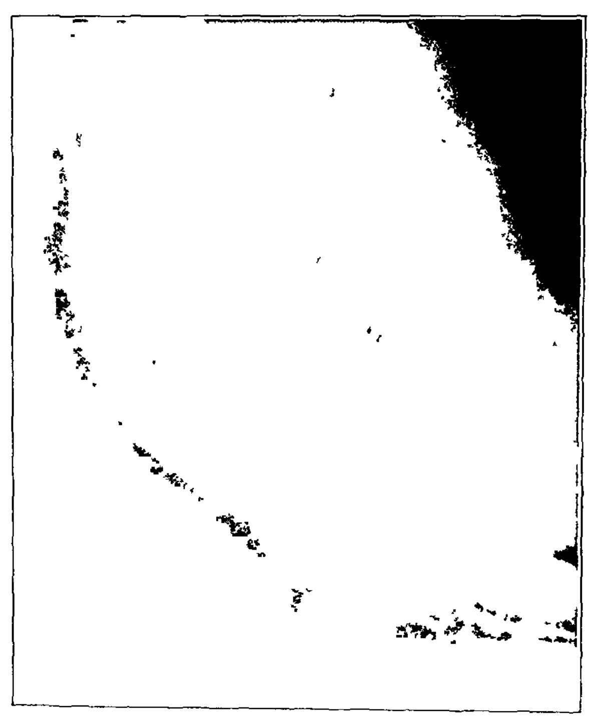

Fig. 1-B

Anteroposterior and lateral views of the right elbow, showing irregular bone absorption and vertical periosteal striations.

BLADE-PLATE FIXATION

Report of a Case

BY IRWIN A. JASLOW, M.D., SAYRE, PENNSYLVANIA

From the Section on Orthopaedic and Traumatic Surgery, Guthrie Clinic and Robert Packer Hospital, Sayre

Blade-plate fixation of intertrochanteric and subtrochanteric fractures of the femur, as well as of high femoral osteotomies, has been described by Moore and has proved its efficiency in a number of cases in the experience of the author. A second angle has been added by Blount, and this has broadened the variety of cases in which this form of internal fixation can be used. This wider use includes such conditions as the correction of coxa vara and the treatment of old ununited fractures of the femoral neck, as well as of fresh ones. In recent fractures, an abduction osteotomy is performed to convert a sheering fracture into an impacting one.

In the usual case, with a firm fixation of the blade-plate, no plaster is required postoperatively. The use of coarse-threaded screws enhances the efficiency of the fixation, as these threads grasp the cortical and cancellous bone more firmly and are less likely to be stripped under excessive strain.

In the case here reported, blade-plate fixation was performed and unusual sequelae developed. In this particular case, plaster fixation was used for the first six weeks for added protection because of the known alcoholic habits of the patient, which, incidentally, were responsible for both the first and second fractures. The case is unusual in that the refracture was obviously not through the old line of fracture, but took place under the sturdy and well-fixed blade-plate. Evidence of the firm fixation was inferred from the fact that it was possible to rebend this plate back into normal alignment. In doing this, the strain was thrown primarily upon the screws used for fixation.

FIG. 1

Comminuted fracture on admission, November 11, 1945.

CASE REPORT

A white male of sixty-six years was admitted to the Hospital on November 11, 1945, after having fallen downstairs. He was suffering from a comminuted subtrochanteric fracture of the left femur (Fig. 1). Skeletal traction was applied, and the patient was made comfortable in bed. In view of the patient's age, it was felt desirable to make him ambulatory as quickly as possible. Therefore, three days later, open reduction was performed and internal fixation was effected with a Moore blade-plate with a three-inch blade and a five-inch plate, which was fixed to the femoral shaft by seven screws. A plaster hip spica was applied and was left on for six weeks, following which the patient returned to the Hospital for removal of the plaster. While roentgenograms did not reveal bony union of the fractured femur (Fig. 2), the fixation was firm enough to allow the patient to be ambulatory on crutches. The patient returned to his home, using crutches and bearing partial weight on the left lower extremity, without untoward pain or difficulty.

Sixteen weeks after the open reduction, the patient was readmitted to the Hospital, after having fallen downstairs again on the previous evening. The patient felt some discomfort at the old fracture site, but no real pain,

FIG. 3

FIG. 4

Low-power and high-power photomicrographs of sections of tumor, showing sheets of round cells with hyperchromatic nuclei and little stroma.

demineralization of the parietal bones. Roentgenographic examination of the chest was negative for signs of pulmonary metastases. No roentgenograms of the lower extremities were made.

A section for biopsy was removed from the tumor of the right elbow and from the epitrochlear lymph nodes. Although this was a very minor surgical procedure, the patient reacted very poorly, and bled so profusely that it was necessary to give him several transfusions to keep him from becoming exsanguinated. At operation, the tumor had a spongy consistency, was beefy red, and was highly vascular.

Histological examination of the tumor showed large sheets of round cells with hyperchromatic nuclei growing without orientation or polarity. Some "rosettes" were present, and there was little stroma in this tumor (Figs. 3 and 4). These findings, together with a history of a retinoblastoma, confirmed by pathological examination, led to the diagnosis of metastatic retinoblastoma of the right elbow. The lymph nodes showed the same reaction.

Treatment consisted of transfusions of whole blood and plasma; 1,500 cubic centimeters of blood and 1,000 cubic centimeters of plasma were given during the patient's hospital stay. He was also given a high-vitamin and high-caloric diet, supplemented by substantial doses of vitamin K. Deep x-ray treatment, totaling 2,000 roentgen units, was given to the right elbow and axilla. However, the patient became progressively weaker, and he died nineteen days after admission.

COMMENT

This case is interesting from the viewpoint of the roentgenographic appearance of the metastases of this tumor to the long bones, which is not an uncommon complication of this disease. Several roentgenologists viewed the films of the right elbow and made the diagnosis of osteogenic sarcoma. However, the finding of a similar lesion in the humerus, with the biopsy findings, led to the final diagnosis. The roentgenographic appearance of the long-bone metastases of this retinoblastoma was indistinguishable from that of an osteogenic sarcoma. Clinically, the unusual youth of the patient, lymph-node metastases, and multi-

and only minimum increase in discomfort on motion of the left lower extremity. However, there was marked deformity, and roentgenograms revealed that a new fracture had taken place and that the plate had bent (Fig. 3). There was marked lateral bowing, shortening, and adduction deformity, correction of which was necessary for a good walking leg. The following morning, preparations were made to remove the plate and bend it straight, or to replace it with another plate for internal fixation. Before doing this, however, it was decided to try a closed reduction. Under pentothal anaesthesia, with the patient lying on the affected side and the pelvis held by a strong assistant, the femur was carefully and firmly manipulated, until the limb was clinically straight with no shortening and no bowing. Considerable force was used in doing this. A roentgenogram was taken at this time to confirm the fact that the plate had not been broken (Fig. 4); and, when this had been determined the patient was discharged, without further fixation, for convalescence at home in bed. Later roentgenograms showed solid bony union with no change in the position of the fragments or of the plate (Fig. 5).

DISCUSSION

This case demonstrates the dependability of blade-plate fixation under unusual stress and strain. Coarse-threaded screws, by biting deeper into the bone, seem to offer firmer fixation than those with finer threads. It would appear advisable to use the coarse-threaded screws in almost all cases of internal fixation.

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Moore, A. T.: Blade-Plate Internal Fixation for Intertrochanteric Fractures. J. Bone and Joint Surg., 26: 52–62, Jan. 1944.

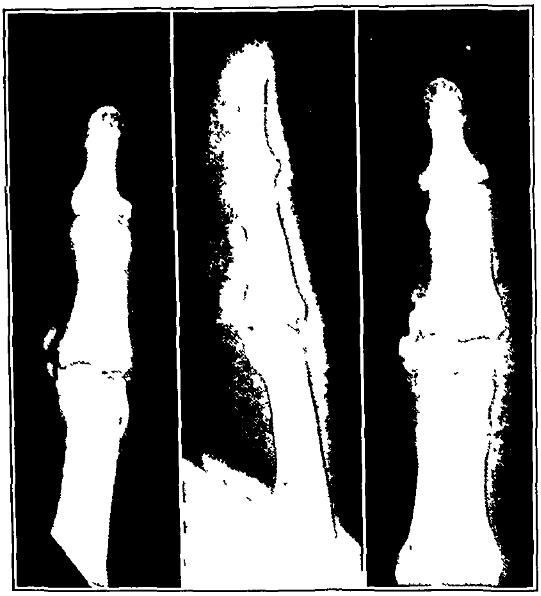

FIG. 1

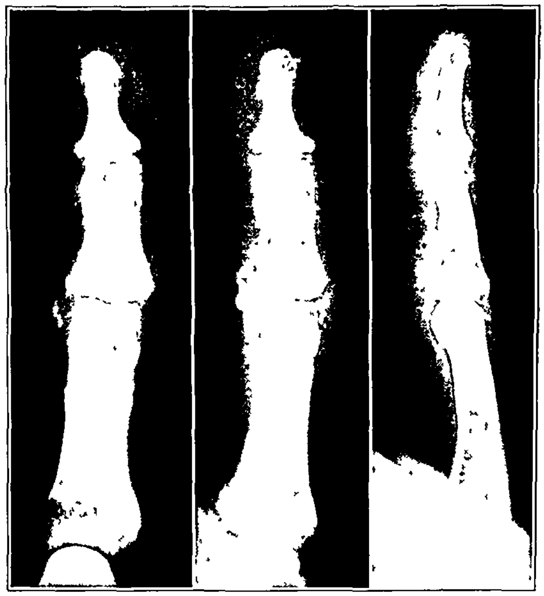

FIG. 2

Fig. 1: Note irregular calcification in soft tissues, especially in the volar and ulnar aspects of the joint. The deposits are amorphous in type.

Fig. 2: Note almost complete disappearance of calcareous deposits after three weeks of fixation and rest.

Physical examination of the left index finger showed it to be uniformly swollen at the proximal interphalangeal joint. The skin was rather taut around the joint. The temperature of the affected part was considerably increased. The finger was held in extension of 180 degrees, and any attempt to flex it, actively or passively, beyond 165 degrees caused severe pain. Palpation showed the point of maximum tenderness to be along the ulnar aspect of the joint.

There were no systemic symptoms, and no other joint was affected. All laboratory tests done at this time, including sedimentation rate, complete blood studies, calcium determination, and uric-acid determination, were within normal limits. Roentgenographic examination revealed irregular calcification, amorphous in type, in the soft tissues on the volar and ulnar aspects of the proximal interphalangeal joint of the left index finger.

Treatment: The finger was put at complete rest by the application of a skin-tight anterior splint of molded plastic. This fixation gave the patient immediate relief; it was maintained for two weeks. At the end of that time, the finger was taken out of the splint several times daily, exercised, and then replaced in the splint. At the end of the third week, all swelling had disappeared, and the range of motion at the affected joint was from 180 degrees to 70 degrees, and painless. Roentgenographic examination at this time showed that most of the calcareous material had disappeared; only a trace still remained in the tissues.

DISCUSSION

This case closely resembles that great number of cases in which there are calcareous deposits in the rotator cuff of the shoulder joint, associated with an acute onset of symptoms. The etiological factors behind this pathological process are still not clear. It is obvious, however, that the local disturbance of calcium metabolism, in these cases, is in response to some other factor. The case suggests that the factor sought for may be either some focus of infection or an allergy. It may well be that, in the presence of one of these two factors, the local disturbance of calcium metabolism in the soft tissues about a joint is the response to a local exciting cause. The exciting cause may be repeated traumata to the affected tissues. Such traumata may readily escape the notice of the patient; frequently no history of injury is obtained. This possibility at least deserves more investigation and experimental study.

1. VASKO, J. R.: Calcareous Tendinitis of a Flexor Tendon of the Finger. Report of a Case. J. Bone and Joint Surg., 28: 638–640, July 1946.

first and second lumbar vertebrae. During the first twenty-four hours, the enuresis disappeared completely; and, although it recurred, it gradually diminished, and within a week had stopped. The flexion of the legs improved 60 per cent., and the spasticity, together with the pain, disappeared.

Girdle pain may also be caused by a congenital stricture of the canal, as evidenced by the following case.

CASE 2. N. F., a policeman, twenty-nine years old, had suffered from intermittent girdle pain as long as he could remember. Three years previous to our seeing him, the pain had become so severe that he was unable to move his lower extremities. After some treatment and rest, he regained the use of his limbs, but the severe pain continued. He had sought advice at many hospitals and clinics, and various diagnoses had been made,—"sciatica", "rheumatism", syringomyelia, and gout. Roentgenograms were taken of the spine and lower extremities. These were negative, as was also the Wassermann reaction. His pain, which at first could be favorably influenced by rest, became worse, and did not improve even when he was in a recumbent position. Physical examination revealed only a slight limitation of motion between the third and fourth lumbar vertebrae. Despite the negative roentgenograms of the spine, a suboccipital injection of 40 per cent. lipiodol was given. In one film, taken two and one-half hours after injection, the lipiodol had stopped at the upper end of the fourth lumbar vertebra. At the time the laminectomy was performed at the level of the third and the fourth lumbar vertebrae, we saw that the lamina of the fourth vertebra had slipped in front of the third vertebra. As a result, a sharp angulation had occurred. The lamina of the fourth vertebra had become hypertrophied so as to fill most of the spinal canal. All the abnormal bone causing the stricture of the canal was removed. Within twenty-four hours after the operation, pain had diminished, and at the end of a week, the patient could move freely. After a fortnight the pain had disappeared, and he was able to walk normally.

The writer has made a number of observations which seem to indicate a causal relationship between stricture of the spinal canal (spina bifida) and certain developmental

FIG. 2-A

FIG. 2-B

Fig. 2-A: N. F. Roentgenogram shows spine to be apparently normal.
Fig. 2-B: Roentgenogram taken two and one-half hours after the suboccipital lipiodol injection Lipiodol remains at the upper end of the fourth lumbar vertebra.

FIG. 2: Showing expansion of lesion by May 12, 1945.

tissue, heavily infiltrated with plasma cells and macrophages. A few neutrophils, eosinophils, and lymphocytes are present, also. Occasional giant cells are seen. There are a few areas of early necrosis with pyknosis and karyorrhexis. A careful search for organisms discloses a few suggestive ones in the giant cells, and occasionally in the intercellular tissue. These are perfectly round and about the size of lymphocytes. A few bits of newly formed bone are present in the periphery of the granulomatous area. Histological appearance is consistent with the diagnosis of torulosis of bone."

The laboratory report stated that *Cryptococcus neoformans* or *Torula histolytica* had been grown on the culture, and that the organism was pathogenic to mice. This organism was not present as a laboratory contaminant. Because the type of organism present was pathogenic to mice, this report coincided with that of the pathologist; and the diagnosis was believed to be definite. Roentgenograms of the pelvis, taken on June 11, showed the lesion to be expanding. A urinalysis was negative, and a seventy-two-hour sputum culture was negative for fungi.

FIG. 3

On August 1, 1946, no further involvement is seen. Thirteen months have passed since complete excision of the involved area. Note the new-bone formation at the superior cortex of the right superior pubic ramus. This area may or may not have been involved, but is healed now.

On June 28, the major portion of the right inferior pubic ramus was removed surgically. Roentgenograms, taken on July 12, showed that all the infected material had been removed. This time the pathologist's report stated that there were a few round cells and occasional giant cells, but that none of the granulomata seen in the previous section were found.

Penicillin therapy was started on June 28, and continued until 1,320,000 units had been given. Sulfadiazine was given for two weeks, with a total dosage of eighty-four grams.

The patient made an uneventful recovery, with complete healing of the soft tissues in the usual time. He was discharged from the Hospital in July 1945, and his condition was followed in the Out-Patient Clinic.

On August 30, 1945, the patient stated that he felt fine and had gained twenty pounds. He wanted to go to work, and was allowed to do so. He was seen monthly, and roentgenograms were taken every two or three months. His only complaints were occasional cramps in the right thigh. He was doing when last seen, on August 8, 1946. Roentgenograms taken on August 1 showed no further invol or pelvis.

one-half inch medial and parallel to its insertion. The capsule is then incised parallel and one-half inch lateral to the glenoid margin. The instrument carrying the suture is placed intra-articularly through the rent in the capsule (Fig. 1,*1*) and, by up-and-down motion, a hole is easily drilled into the osseous glenoid margin. The assistant grasps the suture and the instrument is withdrawn (Fig. 1,*2*).

In Figure 1,*3*, the suture is pictured just before imbrication of the cut capsular edge. A needle, threaded with one end of the suture, then pierces the area of the capsule selected by the surgeon to be sutured to the roughened osseous glenoid rim. Four sutures are placed in a similar manner, and all four are tied (Fig. 1,*4*). The instrument described here was used in the repair of nine shoulder joints for recurrent dislocation, according to Bankart's procedure.

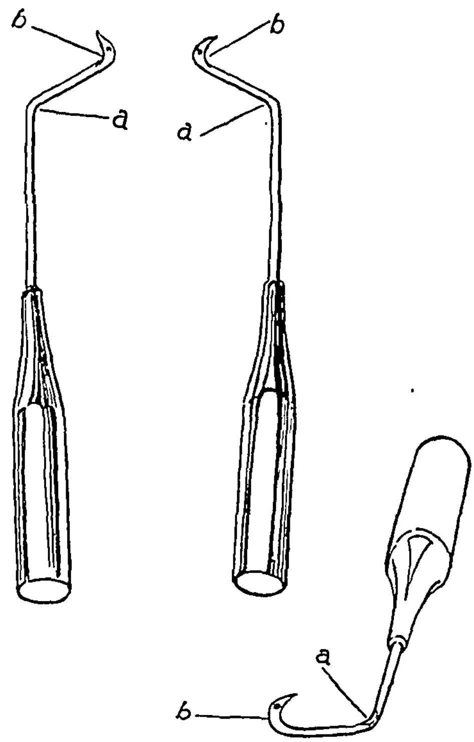

FIG. 2
Suture carrier.
Instrument at left is designed for use on the right shoulder; the one at the right, for the left shoulder.

DESCRIPTION OF SUTURE CARRIER

The instrument is seven and three-quarters inches long. The handle is heavy, and lies comfortably in the hand. At the height of seven inches, the handle forms an angle of 110 degrees. The head of the instrument is turned toward the surgeon, and forms an angle of 90 degrees with the handle (Fig. 2). It ends in a very sharp point, shaped in such a manner that up-and-down motion of this instrument enables the surgeon to drill a hole into the bone. Approximately one-quarter of an inch away from the tip of the instrument, a hole is drilled to permit the threading of a suture. The edges of this hole are smoothed down to prevent the suture from being cut as the instrument pierces the bone.

The instrument is made of tempered steel and is not flexible. It may also be used to advantage in other operative procedures requiring suturing of soft structures to bone, such as tendon transference.

NOTE: The writer wishes to thank Mr. Edmund J. Gernant, bracemaker, Orthopaedic Service, Pratt General Hospital, for his help in designing this instrument.

CORRECTION

Dr. Walter P. Blount participated in the symposium on Fractures of the Hip, presented at the Annual Meeting of The American Orthopaedic Association in June 1946. Through an error, his part in the discussion was omitted. It should have appeared after that of Dr. Mary Sherman, on page 358 of the April 1947 issue of *The Journal.*

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: The first two speakers have demonstrated conclusively that there is an unsolved problem in the management of the complications of fracture of the neck of the femur. Non-union, which is preventable, is being eclipsed in importance by aseptic necrosis and degenerative changes. Several measures have been suggested for the prevention of these complications, but a yet there has been no satisfactory solution. We must remember that most of the patients are old and feeble Most of them will not recover completely. Anatomical perfection is not required. The patient's opinion c the result, as well as that of the surgeon, should be considered in evaluating the treatment.

In this connection, let us look again at the roentgenogram of a high Schanz osteotomy, thirteen year after the operation and sixteen years after the fracture [Slide]. There has been progressive degenerativ change with loss of the joint interval, some destruction of the head, but good position. The appearance i like that of the last case shown by Dr. Sherman. There is obviously marked restriction of motion. Clinica examination shows sufficient flexion to eliminate backache. The patient has no appreciable pain in the hip and is happy with the result. I think that, in this case, osteotomy was preferable to primary arthrodesis, a suggested by Dr. Gill. If pain does appear in such a patient, arthrodesis by simple pin fixation is much more likely to be successful than is primary arthrodesis.

I was impressed by Dr. Gill's figures, showing success in only 60 per cent. of the patients. It should be noted that, in his cases, the hips with successful fusions had been placed in abduction. In my experience, this position is likely to give an unsightly limp, considerable fatigue, and back pain. It is my suggestion that osteotomy be performed early, and that arthrodesis be reserved for the unsuccessful case.

With osteotomy, there are various possibilities. If the patient is not too old, and if the head is alive, the chances are that bony union will occur with a satisfactory range of motion, no pain, and good stability. The likelihood of aseptic necrosis with significant degenerative changes has been diminished by the osteotomy. The shearing force has been eliminated, and adequate circulation is restored rapidly.

If degenerative changes occur in spite of the osteotomy, a good operation has been performed for the treatment of the arthrosis. The patient may go through life without the need for further treatment. If an arthrodesis or an arthroplasty becomes necessary, the local mechanical conditions have been made more favorable for a successful outcome of the palliative operation.

If we could select in advance the cases which will do poorly, we would all agree to the institution of more radical measures to improve the prognosis. A bone graft, in addition to pin fixation, influences the union favorably. According to Dr. Harris and some of the other speakers, the likelihood of degenerative change may be increased by this procedure. I advocated a high femoral osteotomy, to be performed simultaneously with the reduction and fixation. Dr. Charles Pease of Chicago does this routinely with the use of a curved blade-plate, as indicated in the slide. This is actually an osteotomy, as described by Dr. Leadbetter. As internal fixation has become perfected, the Shanz and the McMurray-Putti-Leadbetter procedures all become more alike. In the fresh case, I prefer to fix the fracture with pins, in addition to fixing the osteotomy with a blade-plate. This is to prevent gross displacement. In the treatment of established non-union, this fixation is not necessary, because the fibrous union serves to hold the head and neck in position.

If one accepts simultaneous operation as a desirable procedure in some cases, our criteria for selection should be better established. We have been asked for a statement of our present reasons for augmenting ordinary internal fixation. There is certainly no doubt about the following: (1) senility and osteoporosis, (2) delayed reduction, and (3) verticality of the fracture. I have come to regard any one of these as an indication for the performance of an immediate osteotomy.

It has been argued by some that, if the Schanz osteotomy at the level of the lesser trochanter is good, the McMurray-Putti-Leadbetter type of procedure is better, because it directly underpins the head. I cannot agree. As demonstrated previously, the angulation of the fragments in the Schanz osteotomy underpins the head without encroaching upon the hip joint. I have two primary objections to the use of the very high displaced osteotomy in the treatment of non-union. The first is the inescapable increased limitation of motion at the hip joint. The second is instability. Recently I examined three selected cases from a large series of McMurray osteotomies for ununited fracture of the neck of the femur. In each of the cases a positive Trendelenburg sign was found. If we are to accept the patient's evaluation, the operation produced satisfactory improvement. However, an unstable hip with a positive Trendelenburg sign must be translated into fatigue and disability.

When internal fixation is used, the second objection of instability is largely overcome. It is now possible to angulate the trochanter away from the ilium so that the function of the abductors is re-established. The extremely ingenious operation, suggested by Dr. James Dickson, provides excellent mechanical relations. It will certainly produce prompt bony union at the site of the fracture. The only doubt in my mind is with regard to the late results. Will the additional operative trauma predispose to aseptic necrosis?

FIG. 2

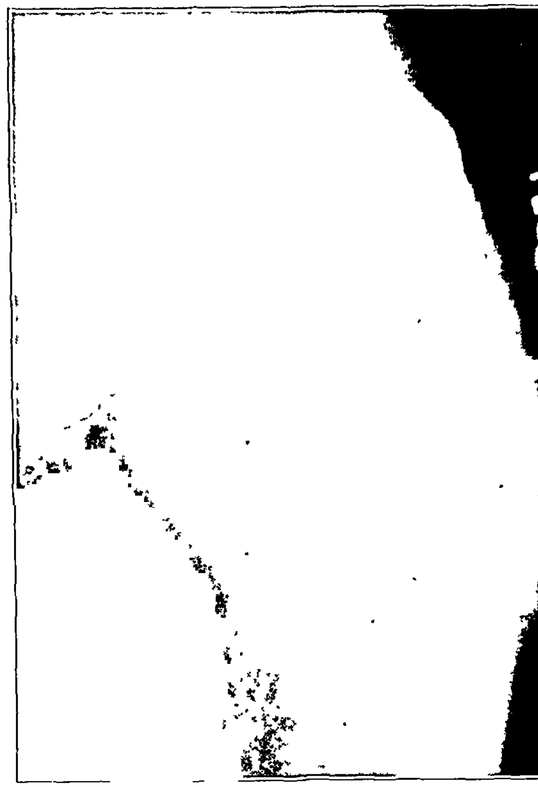

FIG. 3

Fig. 2: Blade-plate fixation after removal of the hip spica on January 3, 1946. Clinically the fracture is solid, but there is no roentgenographic evidence of bony union.
Fig. 3: Roentgenogram showing refracture and bent plate on February 26, 1946.

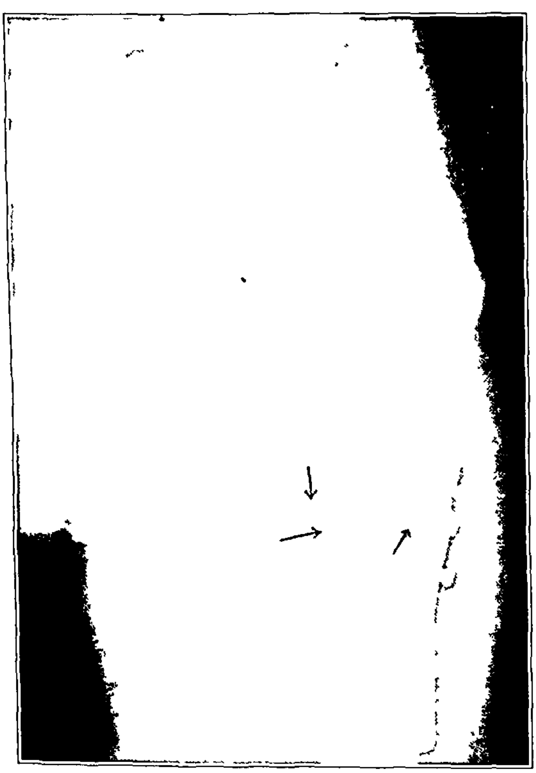

FIG. 4

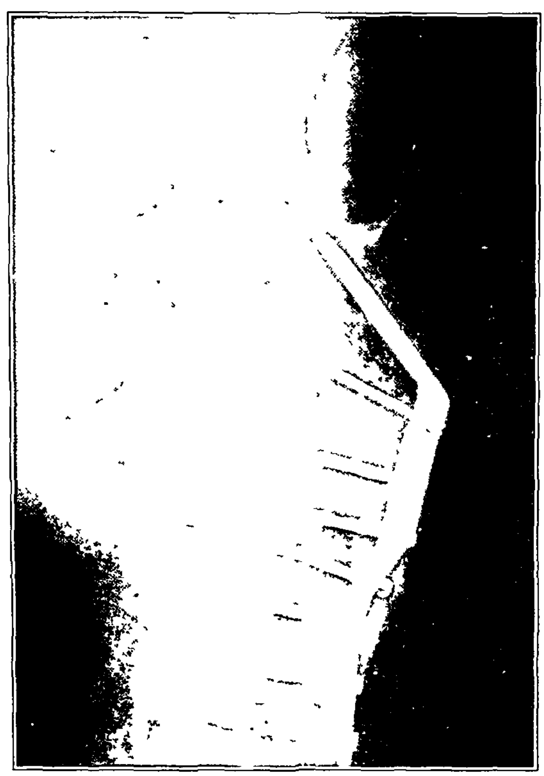

FIG. 5

Fig. 4: Roentgenogram taken after manipulation; the plate shows a reverse curve and reveals that the most recent fracture (arrows) passed through what was intact cortical bone, rather than following the old fracture line. In the course of the manipulation, the middle screw has obviously been loosened.
Fig. 5: Roentgenogram taken October 30, 1946, reveals solid bony union. Apparent change in position is due to external rotation at time film was taken.

HAND SURGERY

Presidential Address *

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

It is a pleasure to see the American Society for Surgery of the Hand established and on its way. This Society was born from the enthusiasm of the officers of the late War, who reconstructed the hands of our wounded. It was found by many that hands could be reconstructed and that the results were good.

Why are we banded together in this Society? What is the interest that we share? It is in part the search to overcome the difficult, as a chase for the will-o'-the-wisp. We are beginning to catch up with it; we are commencing to learn how to reconstruct such an important and indispensable organ as the hand. We have found that the more we delve, the more fascinating becomes this field. It is vast and ever expanding, including as it does most of the ailments of the extremities and of all of their tissues and structures. There is plenty of room in this field for mental acrobatics, the subject being sufficiently wide to occupy a man's whole interest. In diagnosis alone, there is much to learn and much that is alluring. It is fascinating to plan and to carry out an extensive reconstruction. This involves all the mechanics of the hand and the action of the nerves and vasomotor system, bringing useful motion, sensation, and nutrition. It is the big field of surgery of the extremities in miniature, and includes all the principles of these tissues. It is the jewelry of orthopaedic surgery. There is also the human interest—the social side—for most men earn their living by their hands. How much it means to the patient to restore to him what he has lost, when that loss is the use of his hands!

Our Society is composed of men with a kindred interest, for mutual benefit; for altruism, not unionism; and to increase and disseminate knowledge of the hand in every phase of hand surgery. We should encourage men to enter this important field, and should promote research in it.

A function of this Society should be to maintain an evaluation bureau or registry to determine and tabulate all methods, and to promote those which yield the best results. Another function should be to maintain a committee to aid research workers. It could act in an advisory capacity, encouraging them in meeting problems; and also in coordinating and in preventing duplication of work. Stimulated by our common goal of advancement, we will find many other ways to further surgery of the hand.

Surgery of the hand has lagged behind in surgical progress. Surgery of the foot, which started with wrenchings and tenotomies, has gone ahead. It was not from any lack of importance that surgery of the hand lagged. The obstacle was that the repair of the hand presents an intricate, complex problem. Reconstruction of hands is now successful, as shown by the fine results achieved by the many men who did this work in the Army and elsewhere. In nine General Hospitals, to which the care of hands was assigned, many thousands of hands were treated. For the first time in any war, through the foresight of Surgeon General Norman T. Kirk, in our Army, hands were treated as an entity. This viewpoint of having hands repaired by men trained in this specialty, hand surgery, was responsible for the good results.

In the mass production of these systematized hospitals, it was demonstrated thoroughly that the hand should be treated as an entity; and it is hoped that this classification, the merits of which have been proved in this War, will be perpetuated. This applies also to organized civilian hospitals and to private practice.

The hand specialist is not a tissue specialist; his work is regional or anatomical, just as with the specialties of eye and ear, or nose and throat. His background must include the fields of the three tissue specialties—plastic surgery, neurosurgery, and orthopaedic surgery—and he must treat the region as a whole. Hand reconstruction is intricate, and it cannot be learned in a few months. It should even include rehabilitation and the social aspects.

The hand as a mechanical unit starts at the elbow, but dynamically it starts at the opposite cerebral cortex. The hand specialty is not like palmistry, which stops at the wrist, but in a broad sense it should include the whole dynamic problem which affects the use of the hand. The nerves of the brachial plexus and of the arm are mostly hand nerves; the hand is dependent directly upon them. Since the hand is in fact the important part of the arm, the object of the arm is to innervate and support the hand. As Rowley Bristow has stated: "The surgery of the upper extremity is the surgery of the hand".

The best results in our Army were not obtained by passing hand surgery from one tissue specialist to another. The best results were obtained when one man alone, dealing with the problem as a whole, attended to these three aspects. The skin covering was then applied with consideration of hand movements, of deep structures, and of future procedures that could be known only to the one responsible for the whole problem. Although hand surgery probably consists more of orthopaedic surgery than of plastic surgery or neurosurgery, the nerves should be repaired when the hand and forearm have been dissected and lie open, instead of nece-

* Presented at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1947.

SPINA BIFIDA APERTA AND CONGENITAL STRICTURE OF THE SPINAL CANAL*

BY PROF. DR. MÜNIR A. SARPYENER, ISTANBUL, TURKEY

From The Clinic of Infantile and Orthopaedic Surgery, Istanbul

A review of the international literature indicates that, in some cases of spina bifida occulta, the laminae, which should normally meet posteriorly, curve toward the vertebral canal, causing constriction. Recently, the writer has found that the congenital stricture is not always found in the same region as the spina bifida occulta. In some cases, there have been strictures without any evidence of spina bifida. In every case of spina bifida aperta, search must be made for a stricture somewhere in the spinal canal. A recent case proves the correctness of this point of view and is worthy of publication.

CASE 1. M. T. was twenty-two years old when he first came to our Clinic. Four years before, he had been operated upon at another hospital, and a tumor as large as a new-born infant's head had been removed from the lumbosacral region. Despite the operation, there had been no improvement of the enuresis, spastic gait, or flexion of the hips from which he had been suffering. After a preliminary spinal puncture, a suboccipital injection of 40 per cent. lipiodol was given. Although most of the opaque oil stopped at the level of the first lumbar vertebra, a few drops extended down to the second. Laminectomy was performed between the

FIG. 1-A

FIG 1-B

Fig. 1-A: M. T. Roentgenogram taken after suboccipital injection. The lipiodol has stopped at the first lumbar vertebra.

Fig. 1-B: Roentgenogram taken after laminectomy of the first and second lumbar vertebrae. The lipiodol has descended to the lower part of the spinal canal.

* Edited by Leo Mayer, M.D., New York, N. Y.

The American Board of Orthopaedic Surgery will hold its next examination—Part II—in Chicago, Illinois, on January 22 and 23, 1948. The deadline for receipt of completed formal application and application fee is September 15, 1947. Letters of request and applications received after this date cannot be accepted.

Applications for Part II of the examination, as well as correspondence related to the special qualifications to fulfill the requirements for both Part I and Part II of the examination, should be sent to the Secretary of The American Board of Orthopaedic Surgery, Dr. Francis M. McKeever, 1136 West 6th Street, Los Angeles 14, California.

PATHOLOGICAL DIAGNOSTIC SERVICE

The American Academy of Orthopaedic Surgeons by yearly appropriation finances the Registry of Orthopaedic Pathology, a constituent member of the American Registry of Pathology. The Registry is in operation at the Army Medical Museum at present.

The Registry offers full, prompt diagnostic service by skilled men who are particularly interested in skeletal pathology on all lesions of bones, joints, and muscles, including tumors. It also holds cases in its files for follow-up in a very efficient manner.

As this is a nation-wide repository, great quantities of pathological material will accumulate for study and research. Individual cases, however, will be reserved for the referring surgeon, unless permission is given to release the material for general use.

Prepared specimens, gross or microscopic, should be sent by local pathologist or laboratory to: Registry of Orthopaedic Pathology, Army Medical Museum, 7th Street and Independence Avenue, S.W., Washington 25, D. C. If possible, an abstract of the case history and the roentgenograms should accompany the slides or tissue. Quick diagnosis is afforded if properly prepared material is sent.

Surgeons are urged to avail themselves of this advantage offered by the Academy. There is no charge for this service.

Robert W. Johnson, Jr., M.D.
Chairman of the Committee

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Spring Meeting of The British Orthopaedic Association was held at University College, Exeter, and the Princess Elizabeth Orthopaedic Hospital, on April 25 and 26, under the presidency of Mr. George Perkins, M.C.

A symposium on "Surgical Treatment of Tuberculosis of Bones and Joints" was opened by Mr. G. R. Girdlestone, who stressed the importance of strict criteria in the estimation of the results of treatment, and remarked upon the rarity of dissemination of the disease by operation, if the operation is well timed, and preceded and followed by immobilization. He condemned concern with the local lesion to the exclusion of the treatment of the tuberculous patient as a whole, and emphasized the importance of prolonged care after discharge from the hospital. He attached much importance to serial estimations of the erythrocyte sedimentation rate in assessing progress.

Mr. Norman Capener gave a valuable and comprehensive review of tuberculous disease of the spine in 351 patients, emphasizing the differences in the disease and its response to treatment in children and adults. In the first fifteen years, involvement of the lower thoracic (dorsal) area predominated; afterwards the lumbar region was more commonly affected. Of the series reported, 177 patients were treated by arthrodesis, with no mortality within the first nine months. The tibia, which provided the graft, was fractured only once, in contrast with the experience in traumatic cases. Mr. Capener thought that the key to the treatment of thoracic spinal disease might be treatment of the abscess.

Mr. M. C. Wilkinson, speaking of tuberculous disease of the hip, stated that he had found an unstable hip in twenty-two out of fifty patients, treated only conservatively. The value of the operative treatment was measured by its success in securing stability and in safeguarding against recurrence. In seventy-five cases, Mr. Wilkinson's operative mortality was two deaths early and two later. He had used osteotomy, with medial displacement of the distal fragment, but lately he had supplemented this with an extra-articular femoral graft, slid along the upper border of the neck. Operation was performed in the presence of active disease after the patient's resistance had been raised by conservative treatment; and the re-ossification which ensued might be ascribed, perhaps, to auto-inoculation or to the decompression of tuberculous foci. Mr. Wilkinson said that bony ankylosis might take as long as two years, although the hip usually became quite stable before that time. Many roentgenograms of patients so treated were shown. Mr. Wilkinson's view that displacement osteotomy was often of great value in the treatment of tuberculous hip joints was supported by Mr. D. Wainwright, who showed how a combination of osteotomy and an ischiofemoral graft produced rapid bony ankylosis. Mr. Wainwright showed also the result of supplementing long oblique osteotomy by traction, so that not only was apparent lengthening produced by angulation, but also real lengthening by distraction. Dr. J. Delchef advocated early arthrodesis, while the disease was still active. Mr. H. A. Brittain

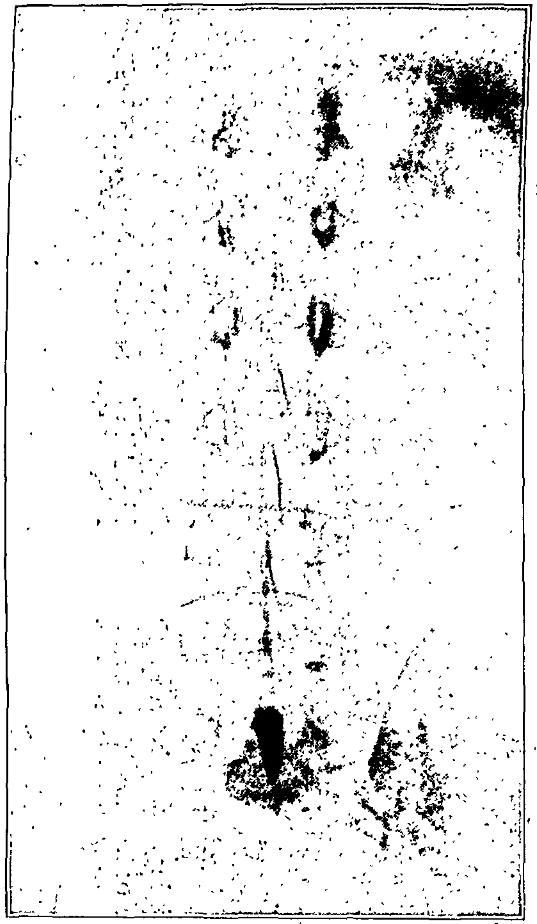

FIG. 2-C

FIG. 2-D

FIG. 2-E

Fig. 2-C: Roentgenogram, taken soon after that shown in Fig. 2-B, shows that the lipiodol has gone down and can be seen like a vertical line.
Fig. 2-D: Roentgenogram, taken after laminectomy, shows that the lipiodol went down without stopping until it reached the fifth lumbar vertebra.
Fig. 2-E: Roentgenogram shows that even after the operation the vertebral canal, which had been enlarged by laminectomy, remained narrow up to the fourth lumbar vertebra, without causing harm.

surgery in such cases. Mr. M. H. Salz showed some cases of synovectomy of the knee joint, and Mr. A. E. Jowett demonstrated arthrograms of this joint with opaque media.

At the business meeting, the following elections were made:

Honorary Fellow:
M. N. Smith-Petersen, M.D., Boston, Massachusetts

Fellows:
F. P. Fitzgerald, F.R.C.S., London
R. D. McKellar Hall, F.R.C.S., Perth, West Australia
H. I. Maister, F.R.C.S., Cape Town, South Africa
S. M. Milner, F.R.C.S., Manchester
S. B. Morris, F.R.C.S., Auckland, New Zealand

Associate Members:
E. W. O. Adkins, F.R.C.S., Stanton-by-Bridge
Ross Bloom, F.R.C.S., London
J. F. Bourdillon, F.R.C.S., Oxford
J. Tulloch Brown, F.R.C.S.E., Motherwell, Lanarkshire, Scotland
A. F. Bryson, F.R.C.S., Loughton
J. E. C. Cherry, M.D., F.R.C.S.I., Dublin
P. N. Cutner, F.R.C.S.E., London
F. W. T. Davies, F.R.C.S.E., Porthcawl, South Wales
T. Denness, F.R.C.S., Delhi, India
T. J. Fairbank, F.R.C.S., Reading
P. A. M. Fitzgerald, M.D., M.Ch., Dublin
G. C. Gordon, F.R.C.S.E., Sheffield
Stewart H. Harrison, F.R.C.S., Birmingham
C. Hollenberg, M.D., M.Ch., London
R. A. King, F.R.C.S., London
Norman S. Martin, M.D., F.R.C.S., London
J. S. Maxwell, F.R.C.S.E., Edinburgh
G. Osborne, F.R.C.S.E., Southport
Marion A. Pearson, F.R.C.S.E., Glasgow
C. C. Slack, F.R.C.S.E., Southport
D. F. Thomas, F.R.C.S., Scunthorpe
F. R. Tucker, M.D., M.Ch., F.R.C.S.E., Southport
R. F. Winckworth, F.R.C.S., Taunton

Surgical Appliances Research Fellowship:
John Gull

It was announced that the 1947 Annual Meeting would be held in Manchester on October 24 and 25.

THE INTERNATIONAL SOCIETY OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY

The first meeting of the Society since the War was held in Brussels on October 3 and 4, 1946. Representing the United States at this meeting was Dr. H. W. Meyerding of Rochester, Minnesota, and at a general meeting it was voted that he should preside at the next Congress, which will be held in Amsterdam in September 1948. Three new countries were admitted to membership in the Society,—Iceland, Mexico, and Turkey. It was decided to increase from forty to sixty the maximum number of members in the Society from any one country.

One of the most interesting sessions of the meeting was devoted to multiple-stage operations and to other methods for the functional improvement of patients after amputation. It was agreed that the most important factors to be considered are suitable treatment of the stump so that it will be more useful and so that it can be easily adapted to a prosthesis; how to deal with the painful stump; and how best to educate the patient to control his prosthesis.

The leading report on multiple-stage operations was given by Mr. George Perkins of London. He mentioned the advantages of the Krukenberg operation for patients who are blind, or who live far from a center where a prosthesis may be renewed or repaired. This operation produces an unsightly stump, by splitting the forearm into two prongs, but it thus renders a prosthesis unnecessary. The patient retains tactile sensation. In Berlin this technique was followed on 600 patients who had lost both arms, and, as a rule, it was done

upper margin; the head of the femur resembles the bumper of a train; the area of ossification shows fragmentation; and the neck is shorter. In malum coxae juvenilis, there is an abnormality of the ossification zone of the neck, displacement of the head, flattening of the capital epiphysis, and diminution of the angle of the neck of the femur. All of the changes indicate a widespread dystrophy, most probably caused by interference with the trophic nerves. The accompanying atrophy of the soft tissues may be partly due to inactivity, but more probably to trophic influences.

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WILLIAM BARNETT OWEN

1880-1947

William Barnett Owen died on February 23, 1947, after a short illness, at his home in Louisville, Kentucky. He was sixty-six. His death brought sorrow to his many friends, by whom he was held in high esteem, both as a man and as a surgeon.

Dr. Owen was a native of Kentucky, the son of Mr. and Mrs. Jordan Owen, with whom he moved to Louisville in 1893. He was graduated from the University of Louisville Medical School in 1903, and completed his training in orthopaedic surgery at the Hospital for the Ruptured and Crippled in New York. He began his practice in Louisville in 1906, and devoted the entire forty years of his professional life to the teaching and advancement of orthopaedic surgery and to the care of orthopaedic patients in the community.

Early in his career as an orthopaedic surgeon, Dr. Owen realized the many disadvantages attendant upon the care of the crippled child in the wards of the average general hospital. With the aid of many of his devoted friends and the cooperation of the Kosair Temple of the Shrine, he undertook the founding of a crippled children's hospital for Louisville. The Kosair Crippled Children's Hospital was opened in 1925 with Dr. Owen as Chief of Staff, a position he held until his death. Under his able direction and guidance, the hospital developed into an institution of over one hundred beds, with the equipment and trained personnel necessary to provide for the many phases of modern orthopaedic surgery.

During the severe epidemics of poliomyelitis which have occurred throughout the country in recent years, the value of this Hospital to the community has been amply proved. It will continue as a monument to his vision and the unselfish service which characterized his life.

As Professor of Orthopaedic Surgery at the University of Louisville Medical School and Chief of the Orthopaedic Service at the Louisville General Hospital, Dr. Owen contributed much of his time to the teaching of orthopaedic surgery. He was an active member of many medical societies, including The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the Southern Surgical Association.

He will remain in the hearts of his family and friends as a kindly man, possessed of an abundant sense of humor, yet unswerving in his adherence to the principles of honesty and integrity which characterized his personal and professional life.

the femur, it is inversely proportional to the length of the stump. Lateral swinging of the trunk aims at two effects: to make sure that the pelvis is kept straight in proper relation to the prosthesis, and to make up eventually for the lack of static equilibrium of the apparatus. To avoid swinging, the stress on the stump should be in the same line as the stress on the foot.

Dr. Sven Kiaer, of Copenhagen, reported that in 1,083 amputations made in the orthopaedic hospital in that city during the years 1936 to 1945, there were found only twenty-six cases of painful stumps. Treatment should be started early, and according to the peripheral or to the central origin of the pain, an operation should be performed on the irritating focus or on the chorda or on the brain cortex.

Dr. Van Assen, of Rotterdam, described re-making of the arch of the foot after excision of the big toe and of the first metatarsal bone. He divides the base of the second metatarsal bone, and fixes the distal fragment to the first cuneiform.

Professor Sandro Marconi, of the *Ospedale Umberto e Istituto dei Rachitici*, Brescia, prefers an amputation through the metatarsal bones to the Sharp, Lisfranc, or Pirogoff methods. He considers the Gritti amputation preferable to amputation at the lower third of the leg. For the upper limb he recommended the Krukenberg operation.

Part of the meeting was given over to the presentation of special reports. Dr. Merle d'Aubigne, of the *Hôpitaux de Paris*, spoke of operations on those wounded in the War, which he had performed in the *Centre National de Chirurgie Réparatrice de Paris*. He pointed out that with cancellous bone it is possible to rebuild a bone extremity, and to obtain mobility in the new joint. In regard to the shoulder, he feels that it is better to aim for ankylosis; while in the elbow joint, it is possible to replace the trochlea of the humerus by a bone fragment cut from the iliac wing. In the knee joint, the destruction of one of the condyles may be repaired, using the patella as a pedicle graft and completing it by grafts of cancellous bone.

Dr. Maurice Guilleminet, of Lyon, told of three cases in which he restored functional opposition of the thumb by transplantation of the flexor pollicis longus, and the local adaptation of the method of medullar pinning of the long bones.

Dr. Meyerding, of Rochester, Minnesota, presented a report on the surgical treatment of primary malignant tumors of bone, which include osteogenic sarcoma, fibrosarcoma, Ewing's sarcoma (hemangio-endothelioma), multiple myeloma, and primary giant-cell sarcoma of bone. He stated that surgical treatment is the best method in such conditions, as it permits biopsy, with gross and microscopic study of tissue, which are valuable aids in diagnosis. The surgical treatment depends upon the location of the growth, the extent of the lesions, and the grade of degree of malignancy, all of which are important factors to be taken into consideration. Routine roentgenographic examination of the thorax should be performed, in order to exclude recognizable metastasis to the lungs. Although efficient laboratory facilities permit early diagnosis, it will be impossible to give to the patient who has a primary malignant tumor of bone an improved prognosis, until all general practitioners carry out routine roentgenographic examination of all painful areas.

In cases of osteogenic sarcoma, of the patients treated surgically, Dr. Meyerding found that 23.4 per cent. lived five or more years; whereas, of those treated by non-surgical methods, no patient survived for five years. In cases of fibrosarcoma, of the twenty patients traced, eight, or 40 per cent., survived for five or more years. Early amputation in these cases of fibrosarcoma, arising from or involving bone, offers the best prognosis. In Ewing's sarcoma (malignant hemangio-endothelioma), the lesion is often confused with inflammatory lesions, especially osteomyelitis. There has been a trend toward radiotherapy of this lesion, after which the tumor may disappear entirely. Dr. Meyerding believes that biopsy and surgical operation are necessary and justifiable in the attempt to clarify a diagnosis. Practically 88 per cent. of his patients had microscopic verification of the clinical and roentgenographic diagnosis of malignant hemangio-endothelioma; of thirty-three patients who had amputations and were traced, eight, or 24.2 per cent., were living five or more years later. Of twelve patients who underwent excision and were traced, two, or 16.7 per cent., were living five or more years later. The value of irradiation therapy is demonstrated by the fact that, of forty-seven patients who were treated by this method and later were traced, eleven, or 23.4 per cent., lived for five or more years. Seven patients who had not received treatment were traced, and were found to have died within five years.

Multiple myelomata are classified among the primary malignant tumors of bone, but are considered more as manifestations of disease of the lymphoid system than as manifestations of bone disease.

Mr. H. Platt, of Manchester, discussed giant-cell tumors of the long and flat bones. He emphasized the fact that tumors must not be confused with bone cysts; they are epiphyseal and not metaphyseal lesions. Stress should be placed on the aggressive character of the tumor for this determines the treatment, which is mainly surgical; roentgenotherapy should be reserved for non-operable tumors. Giant-cell malignant tumors are extremely rare. Mr. Platt stated that he had seen only four, and one of these belonged to the xanthoma type. None of the four patients lived more than a year after operation.

Dr. E.-H. La Chapelle, of Amsterdam, presented his studies of hunger dystrophy of bone, first described in 1919 by Viennese clinicians. Before that time, the disease had been called "rheumatism", "arthritis deformans", "neuralgia", "myalgia", "neurasthenia", or "hysteria". The patients complain of backache and pain in the legs, increased by walking, and they have a waddling gait. They hoist themselves up by

News Notes

The United States Chapter of the **International College of Surgeons** will hold its Twelfth Assembly and Convocation at the Palmer House, Chicago, from September 28 to October 4, 1947, under the general chairmanship of Raymond W. McNealy, M.D. The program includes the presentation of scientific papers, round-table discussions, and operative clinics and demonstrations at various Chicago hospitals.

The First European Rheumatology Congress will meet in Copenhagen and in Aarhus, Denmark, from September 4 to 8, 1947. Discussions will be conducted on the Etiology and Pathogenesis of Rheumatic Fever and Rheumatoid Arthritis, on the Treatment of Rheumatoid Arthritis, on the Social Importance of the Rheumatic Diseases, and on the Bioclimatological Problems of Rheumatology. Information may be obtained from the Bureau of the Congress, 16, Rysensteensgade, Copenhagen V, Denmark.

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The first meeting of the recently organized American Society for Surgery of the Hand was held in Chicago on January 24 and 25, 1947, under the presidency of Sterling Bunnell, M.D. A program consisting of moving-picture demonstrations, presentation of cases, and formal papers was presented at Thorne Hall on the Lake Shore Drive campus of Northwestern University, Friday, January 24; and a second program of formal papers was presented at the Palmer House on Saturday morning, January 25.

On Friday morning, William H. Frackelton, M.D., presented an excellent motion picture, demonstrating the surgical reconstruction of a hand with irreparable palsy of the median and ulnar nerves and a loss of the long flexor of the thumb. In this patient, operated upon at the William Beaumont General Hospital, the sublimis tendons were attached to the proximal phalanges of their respective fingers as a substitute for the paralyzed lumbricales and interossei; the thumb was brought into adduction with the aid of a tendon graft; and a graft was substituted for the injured flexor pollicis longus. The grafts were attached to their respective insertions with the aid of "pull-out" wire sutures. The prolonged operative procedure was carried out in one stage, and the final result was excellent.

Harvey S. Allen, M.D., Michael L. Mason, M.D., and Sumner L. Koch, M.D., then presented three groups of cases, illustrating the care of compound injuries of the hand, division of the nerves and tendons of the hand, and the use of tendon grafts for injuries of the flexor tendons of the fingers. These cases represented various stages in the postoperative care: Some of the patients had recently been operated upon; in others a number of months had passed; and in some sufficient time had passed to evaluate the result.

In the care of compound injuries with fractures of metacarpals and phalanges, Allen stressed the value of the "universal splint" for maintaining the "position of function", which he and Mason had worked out in Italy and found of especial value in the treatment of severe compound injuries.

On Friday afternoon a group of formal papers were presented, all of them illustrated with lantern slides. Darrel T. Shaw, M.D., and Robert L. Payne, M.D., discussed the use of pedicled flaps for repair of soft-tissue defects; Clarence A. Luckey, M.D., and Henry D. Moon, M.D., discussed post-traumatic oedema of the dorsum of the hand; Major J. William Littler demonstrated metacarpal reconstruction with the aid of bone grafts; and Merle M. Musselman, M.D., and William H. Frackelton, M.D., reported their work on ray transference for metacarpal injuries.

The last presentation was a moving-picture demonstration of "Surgery of the Hand", prepared at various naval installations under the direction of George V. Webster, M.D. The immediate closure of amputation defects with the aid of pedicled flaps and subsequent separation of the remaining portions of the fingers, the repair of burn contractures, and the use of tendon grafts, in addition to a number of other surgical procedures, were depicted with excellent color photography.

A second group of papers were presented on Saturday morning at the Palmer House. Discussions of chronic tenosynovitis of the forearm and hand by Thomas W. Stevenson, M.D., and the use of cellophane as an interposition substance by A. W. Farmer, M.D., were followed by the President's Address and by a symposium on tendon transfers. Samuel B. Fowler, M.D., discussed the extensor apparatus of the finger; Julian M. Bruner, M.D., the use of the extensor pollicis brevis to secure abduction of the little finger; Walter C. Graham, M.D., the use of the flexor sublimis to secure abduction of the index finger; and George S. Phalen, M.D., and Richard C. Miller, M.D., the use of the extensors of the forearm as a substitute for the flexors of the fingers.

The next meeting of the Society will also be held in Chicago, January 23 and 24, 1948, but it is planned that subsequent meetings will be held in different cities. The coming meeting will be open to guests, and more specific information concerning the program may be obtained from the secretary, Joseph H. Boyes, M.D., 1401 South Hope Street, Los Angeles 18, California.

Current Literature

Die verletzte Hand. Erkennung, Behandlung und Behandlungsergebnisse der Finger- und Handverletzungen und Infektionen (The Injured Hand). Dozent Dr. Karl Krömer. Wien, Wilhelm Maudrich. 1945. $4.00.

In the Preface of this 300-page volume on the injured hand, the author's preceptor, Lorenz Böhler, stresses the frequency of hand injuries in industry (from 40 to 50 per cent. of the injuries in industry in various countries) and the fact that, in past years, approximately one third of the compensable expense for hand and finger injuries was incurred because of infection and loss of movement (contractures and fixation). Böhler suggests that immediate and skillful surgical treatment of the injured hand is the essential factor in preventing these complications and in securing a successful result.

Böhler states that he employs no chemical agents and no sera, except tetanus serum, and has no medico-mechanical or physiotherapy department. He recommends to others that, for the field of industrial surgery, they lock up the bacteriological, serological, and chemical laboratories and the medicomechanical and physiotherapy institutes, as they are constituted at present, because they only distract attention from what is essential.

Kromer divides his thesis into four parts. The first half of the volume is devoted to the diagnosis, treatment, and results of treatment of recent (*frische*) compound injuries of the hand; the second half to the treatment and results of treatment of infected injuries and of acute infections of the hand; to the diagnosis, treatment, and results of treatment of recent closed injuries; and to war injuries of the hand.

In the first half of the volume, devoted to recent injuries, the author details clearly his conception of the proper immediate treatment of open wounds,—careful cleansing, wound excision, and repair. Every worker in this field would commend the clear-cut principles he has outlined; and the splendid results he has secured speak both for the correctness of the principles laid down and for the manner in which they have been carried out.

Kromer advises cleansing of the field about the wound, but to the wound itself he applies iodine or a dye antiseptic to facilitate wound excision. Conduction anaesthesia is used for the field of operation. Wounds are classified into those which involve covering skin; those with opening of the tendon sheaths; those with tendon injury; those with tendon division; those with injury and division of nerves; those with division of large blood vessels; those with compound fractures of phalanges and metacarpals; and those with compound joint injuries, defects of the skin, and burns. Brief sections on foreign bodies in the hand and on injuries from indelible pencils are also included.

One gains the impression that, in spite of the very serious injuries of the soft parts which are illustrated, the majority of the 1,373 wounds were not severe, for, in the section on Nature of Injuries, the author lists only six with division of superficial flexor tendons, five with division of deep tendons, nineteen with division of both flexors, and twenty-seven with division of extensor tendons. In other words, only fifty-seven of 1,373 wounds of hand and fingers resulted in division of the flexor or extensor tendons. No mention is made in this tabulation of nerve injuries; and the question of nerve injuries is dismissed with a few brief paragraphs and the statement that the results of nerve injuries will be considered in a study to be reported in the future.

The treatment of skin defects with Reverdin grafts and the treatment of burns of the hand with tannic acid and ointments offer a sharp contrast with the skillful treatment accorded wounds of the soft parts in the earlier sections of the volume. A case illustrated by Figure 300, for example, with an extensive loss of covering tissue of the dorsum of hand and fingers, simply "cries out" for a large graft of part-thickness skin, but the reader is left to guess what was done and what result was obtained.

An elaborate statistical summary of forty-five pages follows the detailed discussion of various types of open wounds, and even includes statistics as to the duration of compensation payments made to injured patients. In the second of these tables the author states that, of 1,373 fresh wounds, 1,352 healed without local inflammatory symptoms, eighteen with local inflammatory symptoms, and three with progressive inflammatory symptoms. These statistics, and the fact that only 34.5 per cent. of the 1,136 patients required operative treatment, also convey the impression that the injuries in many of the cases listed would have to be classified as minor.

The section on infected wounds and acute infections of the hand is disappointing. It is rather a summary of the contributions of others than a clear-cut presentation of demonstrated principles and helpful directions as to treatment.

The section on closed injuries of the bones and joints is well illustrated, and demonstrates the excellent results the author has obtained by immediate reduction of complicated fractures and well-designed splinting. Plaster-of-Paris has been used almost exclusively, with the addition of Kirschner wires or fingernail extension in occasional cases.

sitating double surgery. The British custom of including peripheral-nerve surgery in orthopaedic surgery works well, as the neuromuscular aspect is, of course, one problem.

Some points of progress in the reconstruction of hands in the Army may be of interest. All the knowledge gained was pooled among the groups. It was found that, if hands are kept moving, they do not stiffen. New covering was found to be best when made by abdominal flaps in two procedures; or, if the area was not suitable, tube pedicles in one or two more steps were necessary. There should be no raw surface, as this increases stiffening. Free thick skin grafts sufficed for surface burns. Much bone carpentry was done, the favored graft being cancellous bone from the ilium; fixation was accomplished by pinning. Joints were moved to positions of function by elastic or spring splinting. Proximal finger joints responded well to capsulectomy and arthroplasty. Tendon grafts were used successfully when all the principles were adhered to. Many tendon transfers were used, especially for radial palsy, to establish muscle balance in claw-hand, to correct for loss of adduction or opposition of the thumb, and to substitute for any or all of the intrinsic muscles.

Repair of nerves within the hand gave good results, as did also nerve grafts of small diameter. For nerve lesions high in the arm, there was need for collaboration of treatment by one versed in hand reconstruction to keep the hand in the position of function, to keep the joints and tendons moving, and eventually to transfer tendons. Occupational therapy proved to be of far more value than physiotherapy, although the latter was needed for repair of nerve lesions. Many cases of causalgia were cured by preganglionic neurectomy; and, by the use of this procedure, other trophic conditions were improved. There were many reconstructions of digits to give prehension, and in these the importance of nerve supply and motion were recognized. Thumb posts were useful if made short and thick, and phalangization and osteotomy were also used extensively. Pollicization of a functioning index finger from the same hand, with its nerves and blood vessels intact, proved to be very successful.

Last June, I went to England to see what they were doing in hand surgery. Brigadier Furlong, of London, had previously come here for a similar purpose, and had carried back with him what we had to offer. He is now the consultant for hands in the British Army, and I hope he will succeed in making hand surgery an entity in the British Army. Quite a few men in England are interested in hand reconstruction. Excellent recovering after burns and the making of webs are done at their four plastic centers, the plastic surgeons being the ones most interested in hands. I think they have hand cases there with worse burns than we have. Cuthbert reconstructed new thumbs, even grafting a joint into one. Seddon was grafting a ring finger from the opposite hand for a thumb. Pulvertaft showed a dozen excellent results from grafting a flexor tendon plus a paratenon into a finger, using the removable-wire technique. He and Furlong are attempting to form a British society for surgery of the hand, such as ours. Among those interested are Gillies, McIndoe, Molem, Kilner, Barron, and Moore. Let us hope that they will succeed.

Meanwhile, let us make our own Society grow in its important work. I am sure that the day will come when there will be in the various nations many active reciprocating societies for surgery of the hand.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Attention is called to a change in the general qualifications for eligibility to the examination of The American Board of Orthopaedic Surgery. Each candidate who applies for Part I of the examination of The American Board of Orthopaedic Surgery after January 1, 1951, must have the following general qualifications:

GENERAL QUALIFICATIONS

1. He must be a citizen of the United States or of Canada.
2. He must be a graduate of a medical school which has been approved by the Council on Medical Education and Hospitals of the American Medical Association. In the case of an applicant whose training has been received outside the United States or Canada, his credentials must be satisfactory to the Council on Medical Education and Hospitals of the American Medical Association and to the National Board of Medical Examiners; he must have been engaged in the practice of orthopaedic surgery in the United States or Canada for at least three years prior to submission of his application.
3. He must have served an internship of twelve months in a general hospital, acceptable to the Board.
4. *He must have spent a year on an approved surgical residency, subsequent to the completion of his internship.*

NOTE: This change consists of an additional required year of surgical training before the applicant enters on special work in orthopaedic surgery.

No individual may apply for Part I of the examination of The American Board of Orthopaedic Surgery who has not completed at least one year in special orthopaedic training, in addition to meeting the general requirements.

because he was the creator and proponent of skeletal traction as a therapeutic method. In fact, the entire first chapter is given over to the historical background of this method of treatment.

The author points out that the widespread use of this procedure has brought about results of undisputed excellence; but, as with every method of treatment, there are very precise indications and contra-indications for its use; and there is necessity for specialized instruments and a specially trained hospital staff, factors which are not always readily available.

The abuses which have been committed in the application of skeletal traction in cases where it was not indicated, and its use by others than experts, have been the causes of many failures. These failures are to be charged to errors in technique rather than to faults in principle.

However, there are real dangers inherent in the method, and these the author enumerates and describes. The two most important are infection and the possible delay of consolidation which is brought about by excessive traction. Regarding the first, if the patient is surrounded with all the necessary conditions of asepsis and antisepsis, signs of inflammation and infection should be lacking. As to delay of consolidation, the author warns against the use of excessive traction, and he emphasizes the importance of constant roentgenographic control at all times. He states as a fundamental principle the fact that in fractures, once reduction has been obtained, to continue traction for too long a time and not to permit constant contact of the end surfaces of the fragments will bring about the formation of fibrous tissue. On the other hand, the forces of concentric pressure, which act upon the focus, bring about the formation of bone callus. In other words, ideal traction avoids secondary displacement and aids consolidation.

In the course of the book, many interesting problems are referred to. In the general part, there are investigated the experimental study of the reactions of bone tissue before the application of traction; in another section the best and simplest use of skeletal traction is studied. In a special section, the particular application of the different methods of traction is taken up.

Dr. Ottolenghi has drawn from the experience of his daily work, and from the opinions of those whom he considers to be the best writers on the subject. The whole book is well documented, and there is a useful index, as well as a very complete table of contents.

Recent journals have gone more fully into the use of traction during the War, but the author indicates that he has made no effort to include such series of cases.

A Synopsis of Orthopaedic Surgery. A. David Le Vay, M.S.(Lond.), F.R.C.S.(Eng.). London, H. K. Lewis and Company Ltd., 1947. 15 shillings.

It is stated in the Preface that this volume is not intended to be other than a "factual survey of orthopaedic surgery for the use of senior undergraduates, and possibly for post-graduate students working for higher qualifications". Certain subjects, such as rheumatoid arthritis, are treated almost in outline form. The inclusion of a great deal of material in a small space, although desirable from the standpoint of completeness, does not promote clear integration or smooth reading.

A more serious defect is an occasional tendency to present only one side of a debatable question: An example is the citation of anomalous neural-arch centers as the cause of spondylolysis, the contradictory evidence not being mentioned. In a textbook for students, failure to include a bibliography is unjustifiable. With some of the clinical statistics, many readers will not agree. The Esmarch bandage is mentioned, while reference to the less injurious pneumatic tourniquet does not appear. Readers of current American literature will find it unusual to see "clinique" used for "clinical picture" or "symptoms and signs", and "tubercle" as a synonym for "tuberculosis". The author uses the older term "osteitis fibrosa" instead of "hyperparathyroidism".

The illustrations are diagrammatic line drawings, and as such are limited in value. They are clear, however; and, with rare exceptions, accurate. More illustrations might have been added, with benefit. It is unusual to find no representation of a cast, splint, or brace.

In certain departments, however, this textbook is well above the average. Brief discussions of embryology are usually informative. The author presents a modern view of low-back pain and sciatica. Avascular necrosis in general, and that of the femoral head in particular, receives deserved emphasis. The indications and technique of manipulating partially ankylosed joints are covered.

The author has succeeded in treating in a brief space the major orthopaedic disease entities, and many which are of secondary importance. He has appended a detailed and usable index.

Color Atlas of Hematology. With Brief Clinical Descriptions of Various Diseases. Roy R. Kracke, M.D. Philadelphia, J. B. Lippincott Company, 1947. $5.00.

This small atlas will fulfill a very popular demand for a concise presentation of the most important facts in hematology.

Chapters are included on the origin and development of cells, the morphology of the blood cells, and the clinical facts and blood pictures in the various blood diseases. There is a chapter on hematological technique, as well as one on the blood findings in various laboratory animals.

considered that the hip demanded a different treatment from the other joints of the lower limb, because it could be short-circuited from weight-bearing by ischiofemoral arthrodesis.

Mr. J. P. Campbell reviewed eighty-nine cases of tuberculosis of the knee treated at Harlow Wood Orthopaedic Hospital, and found a quarter of the cases to be purely synovial in type. In some patients with osseous lesions, a serviceable range of movement developed. Intra-articular arthrodesis resulted in bony fusion much more quickly in cases of more than three years' standing than in more recent cases similarly treated. Bone-grafting operations were reserved for adults, in whom they supplemented intra-articular arthrodesis or were used to promote bony fusion where resection of the joint alone had failed. Dr. J. Mortens, reviewing seventy-six cases, concluded that arthrodesis should be postponed to the age of thirteen or fourteen, if an epiphysis were involved, but that, otherwise, nine years was not too young an age for the operation.

In considering 118 cases of tuberculosis of the foot and ankle, Mr. B. L. McFarland contrasted the very good, though slow, response to conservative treatment in children with the frequently poor result in adults, in whom dissemination or sinus formation frequently made amputation necessary; conservative treatment, with or without arthrodesis, might be indicated in some younger adults, but in the older patient with tuberculosis of ankle or tarsus, amputation was not merely justifiable, but often imperative.

Mr. J. A. Cholmeley reviewed ninety-four of one hundred cases of tuberculosis of bones and joints of the upper limb, treated in the Royal National Orthopaedic Hospital (Country Branch) in the years 1924 to 1946. The parts affected were: shoulder in thirty-six cases, elbow in twenty-five, wrist in twenty-two, metacarpals and phalanges in ten, and humeral shaft (local lesion) in one. All patients received conservative treatment, supplemented in a few by operation,—arthrodesis of eight shoulders in adults, excision of an elbow, and partial excision of another elbow with drainage for secondary infection, and local excision of the local humeral lesion. Arthrodesis of the shoulder, which was often determined by occupation, gave good results in adults, with bony fusion in every case, whereas recurrence took place in three of the shoulders not operated upon. In two elbows, including the one excised, there was recurrence; there was none in the wrist, metacarpal, phalangeal, or humeral cases.

Sir Reginald Watson-Jones concluded that tuberculosis of bones and joints presented, from the view-point of treatment, two diseases,—one in children and one in adults. Both demanded conservative treatment; in children this usually sufficed, but in adults it should often be supplemented by surgical fusion after quiescence of the disease. He considered that the position was reversed in the case of the spine, which should be more often arthrodesed in children and more rarely in adults, because, in children, conservative treatment of thoracic disease left an unstable spine with increasing deformity; whereas, in adults, the disease in the lumbar area nearly always led to spontaneous ankylosis.

Dr. M. N. Smith-Petersen gave an extremely lucid account of his operation of cup arthroplasty of the hip, illustrated by slides and films. The restoration of shapely, smooth, cartilaginous articular surfaces was demonstrated convincingly.

Mr. W. Alexander Law had found that some 80 per cent. of Dr. Smith-Petersen's cup-arthroplasty operations gave a result satisfying to patient and surgeon, but it was essential that the former should co-operate actively with exercises for two years.

Mr. H. G. S. Korvin concluded, from roentgenographic evidence, that the pathological changes in pseudocoxalgia were those of ordinary aseptic necrosis, and that destructive changes were the biological consequences of the mechanical damage of weight-bearing.

Mr. F. C. Durbin had followed up 525 cases of sciatica and selected 147 cases of sciatica, with neurological signs, treated without operation. Of 123 patients to whom plaster jackets were applied, seventy-nine were relieved or cured.

Mr. G. Blundell Jones had investigated the penicillin content of the synovial fluid of knees with open war wounds, forty-eight hours after a single instillation of 100,000 units. He found retention, in adequate concentration, provided the effusion was not diminishing. Absorption of effusion led to more rapid disappearance of intra-articular penicillin; but, at this stage, penicillin was no longer needed in the joint. Penicillin, given intramuscularly, was not found in adequate concentration in the synovial fluid of the joint, if the joint were completely immobilized.

Mr. A. L. Eyre-Brook showed a patient with bilateral cineplastic forearm stumps and two patients with Krukenberg forearm stumps. The success of the operations (performed by German surgeons) was undoubted, and function appeared particularly good in the Krukenberg stumps on account of the preservation of sensation.

Clinical cases were demonstrated at the Princess Elizabeth Orthopaedic Hospital by its staff and that of the Mount Gold Orthopaedic Hospital, Plymouth. Mr. Norman Capener showed cases of lateral rachiotomy for Pott's paraplegia and his own modification of Neufeld nail-plate fixation of pertrochanteric fractures. Mr. G. J. Lillie showed cases of osteoclastoma and enchondroma, treated by radical excision and grafting. Mr. F. C. Durbin presented examples of arthrodesis of the shoulder, showing short "tri-fin"-nail fixation, and of the elbow, showing the value of excision of the radial head. Mr. G. Blundell Jones showed cases of osteomyelitis of the calcaneus (os calcis) treated by Gaenslen's "cloven-hoof" operation. He presented also cases of osteomyelitis of the femur, discussing penicillin treatment and the need for adequate

muscle strength, as the muscles must then do a good deal of work. The exercises are described in great detail, so that they may be supervised even by a physiotherapist with little experience.

The book contains a number of very instructive pictures. No new ideas are expressed by the author, but it may be a handy reference book for surgeons and physiotherapists who wish to give the patient a precise program for active exercises. In general, the book seems to be an Austrian counterpart of our American reconditioning program. It is much less progressive, however, and is too much controlled by the traditional methods of after-treatment prevalent in Europe.

MUSCLE TESTING. TECHNIQUES OF MANUAL EXAMINATION. Lucille Daniels, M.A., Marian Williams, M.A., and Catherine Worthingham, M.A. Philadelphia, W. B. Saunders Company, 1946. $2.50.

This book represents an up-to-date detailed technical effort toward coordinating and simplifying muscle testing. The muscle-grading tests are arranged in systematized order for subnormal neuromuscular conditions. Although at first designed for patients suffering from acute or subacute infantile paralysis, these tests may be equally valuable in any disease or injury in which a disturbance in the neuromuscular system results in loss of muscle strength, either temporarily or permanently.

The grading and recording of muscle strength were experimented upon with various types of testing, in 1912, by Dr. R. W. Lovett. Gravity tests and prepared shaded charts for visual education were followed by the spring-balance test, devised by Dr. Lovett in collaboration with Dr. E. G. Martin. The results of measuring muscle function by the spring balance were published in 1916.

A helpful chart shows nine different methods of muscle testing which have been used by different persons or groups interested in this phase of work.

The book deals with muscle groups of defined body areas. These groups denote the origin and insertion of muscles, as well as the joint range and nerve distribution. Valuable information concerning prime movers, fixation of specific group action, and synergistic action as distinct from antagonistic action, accompany a list of valuable references. Along with charted muscle groupings are the gradings of good, fair, and poor muscle action, with line drawings to amplify the text.

This book should be of especial value to teachers of physical therapy and to students of physical medicine. It has many diagrammatic drawings and is amply illustrated.

DIE SCHEUERMANNSCHE KRANKHEIT UND IHRE DIFFERENTIALDIAGNOSE (Scheuermann's Disease and Its Differential Diagnosis). Dr. J. E. W. Brocher. Basel, Benno Schwabe & Co., 1946. 11 francs.

The first thirty-six pages of this very short monograph are devoted to a discussion of the disease, the next ten to a consideration of the differential diagnosis, and the last half of the book to the reproduction of some 122 illustrations, depicting a variety of vertebral conditions.

The author calls attention to the fact that Scheuermann's disease, first described in 1920, had been recognized by Schulthess, in 1905, as fixed round back, and later (1910) by Schanz as adolescent kyphosis or vertebral insufficiency.

In the opinion of Scheuermann and others who have studied the condition, it is to be considered as primarily a disease of overexertion. During its early phases, the symptoms consist primarily of segmental stiffness of the spine, round back, and especially of easy fatigability. Before the age of eighteen, pain is seldom noted. However, it is during the latent period that the osteo-arthrotic changes and the wedging of the vertebrae consequent upon disc damage are becoming established. After the eighteenth year, pain in the form of lumbago, sciatica, and other manifestations of low-back insufficiency become prominent.

The condition is found only in the erect human being and is apparently due to stress. As a consequence, the author insists that rest and reduction of the stress to which the back is subject, whether in play or work, should be emphasized. During the formative years, rest, proper posture, and the administration of vitamins A and D are recommended. The author believes that the use of the plaster jacket is justified only in the painful lumbar spine. For the treatment of the thoracic spine, the plaster-of-Paris corset is strictly contra-indicated, in the opinion of the author.

Although this monograph does not seem to merit the dignity of book form, the subject matter is interesting, well presented, and authoritative.

VARICES. SU TRATAMIENTO BASADO EN LA FLEBOGRAFÍA (The Use of Phlebography in the Diagnosis and Treatment of Varices). Dr. F. Martorell. Barcelona, Editorial Labor, S.A., 1946.

According to a brief introductory paragraph, Dr. Martorell first presented much of the basic material in his present book in 1940 before the Fourth National Meeting of Dermatologists. He is now setting forth the results of his own further studies in the use of phlebography in the diagnosis and treatment of varices, as well as those of several of his associates.

By way of background, the book gives in concise order a study of the etiology of varices, including a

only on one side. The operation is of prime concern to the plastic surgeon, because a great deal depends upon the shaping of the flaps and upon the proper covering of the excess raw area with transplanted skin.

Pain in the stump can result from an ill-fitting socket, an irritated neuroma, or from widespread hyperaesthesia of the skin. Of course, the ill-fitting socket can best be remedied by the person who fits the prosthesis. Pain caused by an irritated neuroma is the result of repeated traction from adhesions lying between the neuroma and the muscles or between the neuroma and the skin. To prevent such adhesions, a careful suture of the deep fascia should always be made; or, if the adhesions are between the neuroma and the muscles, the muscles should be made to contract voluntarily within a few days of the amputation.

Mr. Perkins also pointed out that it is not enough to excise a painful neuroma; it is preferable to leave it undisturbed and to excise a portion of the main trunk higher up, at a site where it can be approached through virgin tissue, and where the new neuroma will not be pressed upon by the prosthesis.

As for the treatment of hyperaesthesia of the skin, it presents a difficult problem to the surgeon, since the underlying cause is obscure. The condition is not cured by the excision of portions of all of the main trunks; nor does chordotomy relieve the symptoms, as a general rule.

The cineplastic operation was advocated as one which gives the patient additional sources of power. In an amputation above the elbow, one scapula can be used to control the elbow, the other to rotate the forearm, and the triceps and biceps are used to open and to close the fingers. The cineplastic operation should not be performed unless the muscles to be used have an effective range of shortening. They should be free of scar tissue, and trained by active exercises before the operation.

In the discussion which followed the report by Mr. Perkins, many of the world's foremost orthopaedic surgeons took part.

Dr. Annovazzi, of Milan, gave results of 500 amputations, which had been performed as a consequence of industrial accidents. From his experience, he would advise against the complete primary suture, except in cases where tissues are healthy, and even then, according to the dictum of Putti, drainage should be instituted. Whenever there is the slightest doubt as to the viability of tissue, a secondary suture is recommended.

Dr. Bastos Ansart, of Madrid, presented interesting conclusions from cineplastic operations:

1. Bilateral upper-limb amputees should be provided with a double skin tunnel (Sauerbruch). The extension tunnel is used to obtain flexion of the fingers; the flexion tunnel, to produce flexion at the wrist.
2. When only one arm has been amputated, a cineplastic operation with the formation of a skin tunnel may be tried.
3. Bilateral forearm amputees should be provided with Krukenberg stumps.
4. The Pellegrini tunnelization should be used only in exceptional cases.
5. A patient who has lost his thumb can be given another at the cost of his first metacarpal bone.

Dr. Delchef, Director of the *Neerysche Clinique* in Brussels, and Dr. Van Cauwenberghe showed a patient who had had amputations of both forearms; the Krukenberg operation had been done on the left side on July 23, 1946, and the Pellegrini cinetization on the right on August 17, 1946. The patient was already using his Krukenberg stump and his temporary prosthesis.

Dr. P. G. K. Bentzon, of Copenhagen, Editor of *Acta Orthopaedica Scandinavica*, showed a film on professional readaptation of amputees in the Scandinavian countries.

Professor F. Delitala, of Venice, director of *Chirurgia degli Organi di Movimento*, showed a slight modification of the Krukenberg procedure, in which very short prongs, not longer than the terminal phalanx of the thumb, were left. These do not alter the shape of the stump, and have been found to have considerable strength. Bilateral amputees could be supplied with a phalangization (Putti) on one side, and a shorter digitation on the other for more delicate work.

Professor O. Scaglietti, director of *Bibliografia Ortopedica*, gave the results of his experience at the *Istituto Rizzoli* in Bologna, where 3,844 patients have been examined during the five years of the War, and 1,981 operations have been performed.

Professor Marcel Fèvre, of *l'Hôpital Saint-Louis*, Paris, gave his impressions of the Krukenberg operation as he saw it performed in Austria, at a center for amputees of the German Army at Feldkirch.

Dr. Hendrix and Dr. Kempeneers, of the Orthopaedic Institute and Prosthesis Section of *l'Hôpital St. Pierre* in Brussels, stated their belief that the head of the fibula, or a fibula which is too long, is often a cause of pain when the prosthesis is applied. In such cases, removal of the fibula is indicated, and may be done through a posterolateral incision. Later the delegates to the Congress visited operative sessions at their Clinic, which were presided over by Dr. Robert Soeur.

Dr. Marino Zuco, of Rome, presented a film showing recent developments in prostheses.

Dr. Christian Rocher, of the *Faculté de Médecine* of Bordeaux, spoke of multiple-stage operations on young amputees, which are required by the unequal growth of the skeleton and the soft tissues. He covers a wound, caused by the excision of a terminal scar of a femoral stump, by taking a skin flap from the lateral part of the stump and turning it upside down, using it as a pedicle graft. Stumps which require this procedure should be straightened, as they cannot otherwise be fitted properly with prostheses.

Dr. Scholder, of Lausanne, Switzerland, stated that the importance of lateral swinging of the trunk depends upon muscle atrophy and upon the way the prosthesis fits the stump. In the case of amputation of

The author states that, in surgical reconstruction, the open medullary nailing of the femur has definitely proved itself in old fractures, pseudarthroses, and after the shortening of wounded and of sound femora. In the reconstruction of other bones, the results of medullary nailing are, in general, more unfavorable than those obtained from employment of the earlier forms of treatment.

Intramedullary nailing has stimulated the study of callus formation; for that reason, considerable space is given to this subject in the present edition.

ACKNOWLEDGMENTS

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Analecta Medica (México), **7**: Nos. 2 y 3, 1946.
Anales (Valencia, Spain), **1**: Núms. 1, 2, 3, y 4, 1946.
The Bethesdan (Cincinnati, Ohio), **48**: No. 1, 1947.
Boletín de la Agrupación Médica de Estudios (La Paz, Bolivia), **1**: No. 4, 1945; **2**: No. 1, 1946.
Boletín del Colegio Médico de la Habana (Cuba), **9**: Núm. 12, 1946; **10**: Núm. 1, 1947.
Boletín del Consejo Nacional de Tuberculosis (La Habana, Cuba), Dec. 1946.
Boletines de la Sociedad de Cirugía de Rosario (Argentina), **13**: Nos. 3, 4, y 6, 1946.
Brasil Médico-Cirúrgico (Rio de Janeiro), **8**: Nos. 2–4, 1946.
Bulletin of the Hospital for Joint Diseases (New York, N. Y.), **7**: Nos. 1 and 2, 1946.
The Bulletin of the U. S. Army Medical Department (Washington, D. C.), **6**: Nos. 5 and 6, 1946; **7**: Nos. 1, 2, and 6, 1947.
Child Development Abstracts and Bibliography (Washington, D. C.), **20**: Nos. 3, 4, 5, and 6, 1946.
Cleveland Clinic Quarterly (Cleveland, Ohio), **13**: No. 4, 1946; **14**: Nos. 1, 2, and 3, 1947.
Columbia University (New York, N. Y.), Bulletin of Information, Series 46, No. 35, 1946–1947.
Dolores mortales (Algias-espasmos y distrofias esplacnicas). Por el Dr. Miguel López Esnaurrízar, Mexico, D. F., 1947.
Harper Hospital Bulletin (Detroit, Michigan), **4**: Nos. 2 and 3, 1946; **5**: Nos. 1, 2, and 3, 1947.
Instituto Nacional de Prevision (Madrid, Spain), Anuario, 1945.
International Health Conference (New York, N. Y.), Department of State Publication 2703. Washington, U. S. Government Printing Office, 1947.
Médica (Matanzas, Cuba), **5**: Núms. 5 y 6, 1946; **6**: Núms. 1 y 2, 1947.
The Physiotherapy Review (New York, N. Y.), **26**: No. 6, 1946; **27**: Nos. 1, 2, and 3, 1947.
Revista Médica Municipal (Rio de Janeiro, Brasil), **8**: Núms. 1 e 2, 1946; **9**: Núm. 1, 1946.
The Rockefeller Foundation (New York, N. Y.), A Review for 1946.
Sociedad de Cirugía de Cordoba (Argentina), Boletines y Trabajos, **7**: Nos. 7, 8, y 9, 1946.
United States Public Health Service (Washington, D. C.), The Journal of Venereal Disease Information, **27**: Nos. 10 to 12, 1946; **28**: Nos. 1 to 6, 1947; National Institute of Health, Bulletin No. 188; Public Health Bulletin, No. 294, 1946; Public Health Reports, **61**: Nos. 42 to 52, 1946; **62**: Nos. 1 to 26, 1947; Supplements Nos. 191, 192, 193, and 194.

their hands when ascending the stairs. Roentgenograms show only a slight degree of decalcification and of periosteitis of the pelvis, a small bone crack here or there corresponding to an area of alteration of the bone. Similar changes may be seen in rickets and osteomalacia. Dr. La Chapelle thinks that this type of bone dystrophy should be considered as the initial stage of osteomalacia. In all such cases, the patients had been on a restricted low-calorie diet during a considerable time. All showed a lowering of the serum albumin.

Very similar to this hunger dystrophy is the syndrome described by Milkman in 1930: a patient with a considerable number of areas showing alterations of bone or cracks. Milkman mentioned that his patient had put herself on a reducing diet and lived on orange juice. It is queer that these cracks should be situated exactly on the spots where fatigue fractures generally occur, which proves that the seat of the cracks is determined by a mechanical factor.

Professor Etienne Sorrel, of Paris, one of the scientific directors of the *Revue d'Orthopédie*, professed his belief that penicillin is of great help in the treatment of osteomyelitis.

Dr. Lopez-Trigo, of Valencia, spoke of a new technique of reduction of supracondylar fractures of the humerus.

Dr. Robert Soeur, of Brussels, presented a study of the results of medullary pinning in ninety-nine patients. He stated that the operation gave very satisfactory results in closed fractures of the shafts of the long bones; that it is not recommended in compound fractures; and that it is applicable to a few fractures of the epiphysis,—such as fractures of the surgical neck of the humerus or pertrochanteric fractures.

Dr. Kopits, of Budapest, gave a practical method of joint measurement.

Mr. H. J. Seddon, of the Wingfield-Morris Orthopaedic Hospital, Oxford, showed a valuable film in which the joint movements of the foot, the knee, and the upper limb could be seen.

Mr. B. H. Burns, of London, spoke of diagnosis and treatment of herniation of the intervertebral disc.

Sir Reginald Watson-Jones, of London, presented a review of 1,000 cases of fracture of the spine, giving the various types of fractures and their treatment.

Dr. Pasquali, of Bologna, told of the "fork apparatus" which he had used to reduce thirty-nine spine fractures. By this apparatus, longitudinal traction is exerted on the fracture as well as on the articular process in cases of dislocation. In cases of angulation, the normal axis is restored.

Dr. Scaglietti, of Bologna, gave the results of early treatment by abduction in congenital dislocation of the hip. The hereditary character and geographical distribution of the deformity were considered.

Dr. M. Jaros, of Prague, stated that studies of congenital dislocation of the hip in uniovular twins make it possible to conclude that the cause of the deformity must be sought in the chromosomes. External mechanical factors would be of only secondary importance. Dysplasia of the hip looks very much like a delay in development; it is not caused by roentgenotherapy on the mother, by the overuse of spirits or tobacco, or by infection. This condition might originate in the lack of mixing of populations in some areas of Europe.

Professor Zahradníček, of Prague, spoke of the etiology of coxa plana, and showed a new apparatus for the treatment of congenital dislocation of the hip. The report was followed by a motion picture on the operative reduction of congenital dislocation of the hip.

Dr. Gruca, of Lwów, Poland, stated that since 1933 he had performed a resection osteotomy of the hip in all cases, whereas formerly he had performed arthrodesis. He performs the same operation in all cases where mobility of the joint is an absolute requirement, in bilateral coxalgia, and in tuberculous arthritis of the hip and of the knee on the same or on the other side. Where coxalgia is combined with lumbar spondylitis, he feels that the operation is indicated. Treatment is reduced to half its usual length, the cure is more radical than that following arthrodesis, and the joint remains stable and almost normally mobile. Dr. Gruca has treated ninety cases with successful results in 90 per cent.

Dr. Delahaye, of the *Hôpital Maritime de Berck*, stated that he had had the opportunity of treating a sixteen-year-old boy, suffering from tuberculosis of the right hip, osteo-arthritis of the lumbar spine, and tuberculous osteo-arthritis of the mid-portion of the right foot. The patient was first seen when the lesions had reached a chronic stage. The "varus-adductus" deformity of the foot has been corrected by a cuneiform dorsal arthroplasty; the ten-centimeter shortening of the right femur was treated by the subperiosteal resection of the left shaft of the femur. The Pott's disease healed spontaneously, and pseudarthrosis of the hip joint allowed a fair amount of mobility, while stability is very satisfactory. Anatomical and functional results were considered perfect.

Dr. J.-Ed. Samson, of Montreal, Canada, pointed out that he had performed arthroplasty on the knee more than 100 times, and he gave instances of a few technical details of the operation, and of the importance of early mobilization. Arthroplasty of both knees is contra-indicated, and in any case, should not be done before the patient is twenty years old. Performed under favorable conditions, arthroplasty of the knee gives perfect stability, satisfactory mobility, and a painless joint.

At the 1948 meeting, which will be held in Amsterdam, the following questions will be studied:

1. Treatment of arthritis deformans of the hip.

With reports from Belgium, France, Netherlands, Poland, Sweden, and Czechoslovakia.

2. Closed trauma of the spine.

With speakers from Austria, Spain, United States, Great Britain, and Italy.

ORTHOPAEDIC SURGERY AND ITS PLACE IN THE DEPARTMENT OF SURGERY IN OUR MODERN MEDICAL SCHOOLS*

BY LEROY C. ABBOTT, M.D., SAN FRANCISCO, CALIFORNIA

The first point that I would like to stress is the extraordinary advance that has been made in orthopaedic surgery since the foundation of The American Orthopaedic Association in 1887. While the pioneers in this field undoubtedly envisioned the ever-widening scope in our branch of surgery, I do not believe that they could have foreseen the tremendous development that has taken place. At the present time, orthopaedic surgery represents the largest special field in the department of surgery in most of our medical schools. In the majority of these schools, surgery is divided into so many specialties that the so-called department of general surgery is practically non-existent. It, too, is a specialized line, confined largely to surgery of the abdomen and neck. Nevertheless, under the guise of general surgery, this special branch has maintained control and continues to dominate the entire department of surgery. It is possible that this state of affairs may have been desirable during the early period of our development, but changing conditions have made this domination by a single branch no longer practical or justifiable.

Orthopaedic surgery has come of age and can stand on its own merits. It does not require the guiding hand of any other branch of surgery and, in my judgment, this persistent domination simply has the effect of hampering progress in our field.

These conclusions have not been arrived at hastily, but quite the contrary, being based on personal observation and experience as a student, teacher, and surgeon over a period of thirty years not only in orthopaedic surgery, but also in general surgery, before ecialization was so highly developed. During that time I have had the privilege of romoting the growth of orthopaedic surgery in three of our leading medical schools: alifornia, Michigan, and Washington University in St. Louis. I am entirely in agreement with the idea, advocated by outstanding men in all fields of surgery, that a broad general training and background should be prime requisites to entering a specialized field. Furthermore, the opinions set forth in this paper are not prompted by bias on my part, since my own experience has been most fortunate, especially during the past sixteen years. Conditions have been extremely favorable, because Dr. Howard Naffziger, Professor of Surgery at the University of California Medical School, who is a specialist in his own line of neurosurgery, with an excellent background of training and experience, has very liberal ideas in regard to other branches of surgery.

However, orthopaedic surgery still remains a subdepartment in most of our medical schools, and the heads of such departments do not have the same jurisdiction as the chief of the division of general surgery in decisions involving policies of the medical school, and the arrangement of the curriculum for teaching undergraduate and postgraduate students; nor do they, in most instances, have direct contact with the dean of the medical school as members of the dean's executive committee. Moreover, they do not have complete control of the appointments and promotions in their own departments, nor do they have proper representation in the distribution of the budgets. In the appointment of interns and assistant residents in surgery—in other words, of the men who are chosen for the basic and broad training of surgery—the advice of the head of a subdepartment is seldom sought; neither does such advice, if sought, receive authoritative attention. In no way does the head of a subdivision have equal status with the head of the division of surgery.

At this point it might be interesting to trace the history of orthopaedic surgery from

* Presented as the President's Address at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1947.

For every surgeon interested in the immediate care of open wounds, this volume will prove stimulating and helpful. The results which the author has obtained in such cases are admirable and well worth striving to emulate.

THE INTERNAL FIXATION OF FRACTURES. Charles Scott Venable, M.D., F.A.C.S., and Walter Goodloe Stuck, M.D., M.S. (Orth. Surg.), F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1947. $5.50.

In their Preface, the authors state as the purpose of this work, "to give a factual account of the internal fixation of fractures with emphasis on the causes of past failures and the criteria for future successes".

The presentation of the early history of metal appliances in the treatment of fractures represents an amount of research, and the bibliographies accompanying this and other chapters are a valuable part of the book.

The experimental studies of the use of metals in surgery, as carried out in different countries, have been reviewed carefully.

Clinical observations by different surgeons in various countries have been followed with interest by these authors, whose names for more than a decade have been associated with the study of electrolytic reactions of various metals and alloys to the body fluids. They believe that "a clear understanding of the part which electrolysis plays in corrosion of metals in the body provides an explanation of many of the previous failures".

Reaffirming their belief that conservative closed treatment of most fractures will result in good functional union, they point out that there are very definite indications for the use of internal fixation in fracture treatment, and quote Kennedy's classification of such indications. The Technique of Internal Fixation in various sites is discussed. This chapter should be of real value to the less experienced surgeon, as well as the two long chapters on Fractures of the Upper Extremity and Fractures of the Lower Extremity, which give definite instructions for dealing with different types of fractures.

A chapter is devoted to the account of the efforts to improve metal appliances, through the research of many individuals and committees. In 1941, the Committee on Fractures of the American College of Surgeons appointed a Sub-Committee on Screws and Plates to investigate the entire question. Following the report of this Committee, and at the suggestion of the Committee on Medical Research of the National Research Council, arrangements were made with the Metallurgical and Chemistry Departments of Columbia University to carry out experiments on the four metals which the Sub-Committee had decided met their standards of corrosion resistance, as well as of physical fitness. The tests conducted at Columbia were under the supervision of Professor Colin Fink, head of the Graduate Engineering Department; the animal experiments were carried out at the College of Physicians and Surgeons of Columbia University under the direction of the late Clay Ray Murray. The report of this Committee is included. Again and again the surgeon is cautioned that only a single metal should be used in the patient.

The progress made in the development of suitable nails, screws, and plates is most encouraging; there is need for further research.

The authors have succeeded in presenting a book of practical instructions, as well as a review of the literature dealing with the internal fixation of fractures. It will be found of special value by all surgeons who deal with fractures.

THE 1946 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Edited by Charles F. Painter, M.D. Chicago, The Year Book Publishers, Inc., 1947. $3.75.

Each year the reader of the Year Book of Industrial and Orthopedic Surgery has been impressed by the judicious choice of articles to be abstracted from the journals of the year. To bring together into so small a volume the important new developments in this field, as well as the more significant end-result studies of various conditions, requires careful reading and wise selection. The ability to choose wisely and to evaluate accurately the articles in current literature were gifts which the Editor of this volume brought to his task; they are as evident in this new volume as in those which have preceded it.

Since the Year Book of Industrial and Orthopedic Surgery was first started, in 1940, the Editor has been Dr. Charles F. Painter. His work on the 1946 volume was almost completed at the time of his death, in January 1947. It is most fitting that the publishers have dedicated this volume to Dr. Painter and have included a beautiful tribute to him, prepared by one who had long known him well, Dr. Charles H. Bradford.

The publishers announce that the new Editor of this Year Book will be Dr. Edward L. Compere of Chicago.

TRACCIÓN ESQUELÉTICA (Skeletal Traction). Carlos E. Ottolenghi. Buenos Aires, El Ateneo, 1946.

Dr. Ottolenghi has presented a thorough-going analytical review of the entire subject of skeletal traction. He states that rightfully a review of the entire body of work done by Codivilla should have been included

Surgery, Sir Robert Jones. The Edinburgh War Hospital was my assignment. Sir Harold Stiles was the Surgeon-in-Chief, and he directed a tremendous amount of reconstructive procedures and operations on tendons, muscles, bones, and joints. He was recognized as one of the world's greatest surgeons, and it was not only a privilege to assist him, but it was a revelation to witness his delicate and meticulous dissections which covered the whole field of surgery. It was from him that I first learned the vital importance of an intimate knowledge of anatomy in orthopaedic surgery, and the necessity for a broad general training. His own period of training went back to the days when he was a spray clerk in the surgical amphitheater of the great Lister.

From Edinburgh I went to London to work in the British War Office with Sir Robert Jones. This association with a man of genius was a priceless experience. My good friend, Dr. Robert Osgood, was instrumental in securing this appointment for me, and I cannot refrain from expressing my gratitude to him for his friendly interest, as well as my admiration for the splendid work he did in the organization of orthopaedic centers, as second in command to Sir Robert Jones.

Early in the War, Sir Robert saw the need for immediate and adequate splinting of all fractures on the battlefield, and particularly of compound fractures of the femur. He initiated the use of the Thomas splint in No Man's Land, and you are all familiar with the results achieved. Furthermore, he realized that fractures of the femur were kept in general hospitals in France for too long an interval after injury and consequently could not have the proper definitive treatment. A review of the records of many such patients after they had been sent back to England almost invariably showed an alarming proportion of deformity and shortening. He was responsible for the institution of early removal to fracture centers in Great Britain, where definitive care could be carried out and the fundamental principles of traction and countertraction for restoration of length and alignment could be applied with splendid results.

Other developments in orthopaedic surgery at this time are notable examples of the vision and leadership of Sir Robert Jones. He felt very strongly that the problem of the wounded soldier consisted not only in the immediate care of his injury, but in the complete reconstruction of his mind and body by re-education and rehabilitation. This led to the development of departments of physical and occupational therapy, the latter principally in the form of Curative Workshops. These were created in all British orthopaedic centers. The work accomplished by Sir Robert in this connection aroused so much admiration that he was able to enlist the support of many devoted volunteers, among them the exiled King Manuel of Portugal, who was living in England at that time. In order to stimulate wide general interest in this curative work, Sir Robert established a magazine, appropriately named *Recalled to Life*, which was edited by Lord Charnwood, well remembered for his excellent biography of our own Abraham Lincoln. Later the name was changed to *Reveille*, and it was then edited by the celebrated English novelist, John Galsworthy.

The various orthopaedic hospitals in Great Britain were in charge of leaders in the field of general surgery, all under the directing guidance of Sir Robert Jones.

My second year of service in the Army was spent in several hospitals in France. In the first one, in Paris, the fractures were received directly from the front after first-aid treatment and splinting had been carried out. Therefore, I was able to observe these patients from the very beginning, through their definitive care, and up to the time they were ready for evacuation. These observations left indelible memories. First, I saw the inadequacy of débridement of the wounds by doctors who lacked an accurate knowledge of anatomy. Then I saw the failure to produce length and alignment in compound fractures, because of the use of complicated and altogether unmanageable apparatus. Sepsis was rampant among our war-wounded in those days and was due, in many instances, to faulty and inadequate treatment of the wounds and the neglect of fundamental principles of dependent and adequate drainage, as well as to defective immobilization.

The blood pictures are somewhat disappointing. The purpose of such a book is to aid in identifying the different blood cells. This book falls far short of this purpose, because the nuclear details of the cells are extremely poor and erroneous. The colors are so poor that the important changes in the development of cells, as expressed by the intensity of the blue of the cytoplasm, cannot be followed.

Many of the pictures and much of the material have been reprinted from Diseases of the Blood by the same author; however, in the reproduction, much of the definition has been lost, which makes the color plates of less value than those in the original book.

Parenteral Alimentation in Surgery with Special Reference to Proteins and Amino Acids. Robert Elman, M.D. New York, Paul B. Hoeber, Inc., 1947. $4.50.

The author, a pioneer and distinguished authority on the subject of the intravenous injection of proteins, has summarized the whole subject of parenteral alimentation in this fascinating monograph. He rightly ranks this procedure with anaesthetic agents and aseptic surgical technique in the advance of surgery. All of the various nutritional substances—water, electrolytes, protein, carbohydrates, fat, and vitamins—are considered, but special emphasis is placed upon protein administration, including whole blood, plasma, amino acids, and hydrolyzed protein.

Careful attention has been given to the inclusion of established facts and the exclusion of theory. Thus, the injection of potassium and magnesium solutions, still largely experimental, is barely mentioned. The practical surgeon will appreciate this critical selection. He will also approve of the detail in which the author presents his program. Thus, the question of saline versus water solutions and the relative value of the various protein mixtures are critically evaluated. A program for complete intravenous alimentation is presented, together with proof of its efficacy. A good historical summary of each topic is given, and a complete bibliography is included.

This book should be read by every practising surgeon. He will be surprised at the body of facts that the author has accumulated, and gratified by the application of these new techniques.

Die aktive Bewegungstherapie. Ein Leitfaden zur Nachbehandlung von Knochen- und Gelenksverletzungen. Dr. Rudolf Drobil. Wien, Wilhelm Maudrich, 1945. $3.00.

This book represents ten years of experience in after-treatment at the Surgical Clinic of the University of Vienna, and also the author's experience during the war years. The manuscript was finished in the summer of 1942 and was finally published in December 1944. It consists of 284 pages, printed on very good paper in simple binding.

The author divides his subject into a general part, describing the underlying principles involved in active exercise, and a second part, where these principles are applied to all the joints of the body. In his Introduction, the author states that his book has two aims: to interest more people in becoming physiotherapists and to help surgeons finish their job. He considers a surgeon's work as not finished until function has been restored, regardless of how well the injury has healed.

Active exercises are considered by Drobil to be far superior to passive motion, whether carried out by man or by machine. His physiological arguments are as follows: Any active motion is a very complex process. It starts in the brain, which sends stimuli through relays to the motor nerves and finally to the muscles. However, sensory nerves, stimulated by the mechanical irritation from moving parts, play a paramount role in the performance of a well-coordinated motion, which requires a very intricate play between stabilizing muscles, as well as between primary movers and antagonists. An impaired function means that these complicated processes, which the author compares to a chain, are interrupted in one or more places. Repair work will fail if all the members of this chain are not working properly. Thus, for instance, no passive movement will teach a patient to send stimuli from his brain through his motor nerves, unless he is encouraged to repeat the action as often as necessary until he succeeds. In other words, only active motion will restore proper function.

To avoid atrophy, it is necessary to start treatment early. At the same time, this will prevent contraction and adhesions. When normal function cannot be achieved for anatomical reasons, substitution should be attempted. In cases of stretched and weakened ligaments, increased muscle power should be developed for stabilization of the joint. A shortage of personnel often requires group treatment, which is of advantage, because competition helps the patient to overcome or to disregard his pain. The treatment should be given, however, with consideration for the individual case. Active exercise should be started after proper breathing has been accomplished. Very little equipment is necessary for this therapy,—a floor mat, a ladder, pulleys, sandbags, and different weights.

The rest of the book—by far the larger part—is devoted to a detailed description of the bony, muscular, and ligamentous parts of each joint, and their respective roles in any disability in this region. Accordingly, the exercises vary, but they always progress from a simple motion (assistance is given when necessary) to a more difficult one, performed against resistance. At the end, the exercises are done quickly, requiring considerable

Presidential Address of 1944, "it seems not improbable that various specialties will develop within orthopaedic surgery, as they have in general surgery"; and, as Steindler has said, general medical knowledge is so essential that we should be called orthopaedic physicians, since the term orthopaedic surgeon has become inadequate. He adds also, that that part of physiology covering the mechanics of locomotion is still virgin soil.

With our growth, we must accept increased responsibility. It is the duty of the older men, with broad clinical experience in the care of fractures, to insist that fundamental principles of treatment should be employed with the application of the simplest apparatus that is feasible. The routine use of complicated contrivances which involve penetration of the bone with multiple pins should be avoided. These should be reserved for special cases, where experience has shown that they are absolutely necessary. Complications, some of them serious, are of frequent occurrence in their use, particularly in the hands of the uninitiated. It is common knowledge that the majority of fractures can be successfully treated by the older and more conservative methods without taking unjustifiable risk. As Ryerson has so well put it in a recent article: "The best fracture surgeon uses the fewest gadgets".

The practice of surgery as a specialty in the general field of medicine began about the time of the founding of the American Surgical Association in 1880. Coller, in his Presidential Address before that Association in 1944, quoted the following statement made by the founder, Samuel B. Gross, in the year 1876: "It is safe to say that there is not a medical man on this continent who devotes himself exclusively to the practice of surgery and that American medical men are general practitioners and cover the entire field of medicine, surgery and obstetrics".

This was the state of affairs at the close of the Nineteenth Century, and the practice of the so-called general surgeon embraced what we know today as orthopaedic surgery. However, during the first quarter of the Twentieth Century came what Platt describes as "the abdominal revolution". The general surgeon developed this field with striking success and, with refinement of technique and diagnosis, he has performed surgical feats which formerly would have seemed impossible. Furthermore, with improvement in preoperative and postoperative care, he has extended the field of operation on the gastro-intestinal tract to the older age group and substandard risk patients, with a resultant declining mortality rate. With this emergence of abdominal surgery as a specialty, other special fields have ensued, until at the present time there are twelve divisions in what was formerly known as general surgery. This development has produced a violent reaction in the ranks of the irreconcilables among the older surgical practitioners, notably Bevan, who expressed himself in these words: "The scope of the field to be covered by the American Surgical Association has never, until comparatively recently, been a matter of question. Since the founding of the Association in 1880, it has always been the purpose of the organization to cover the entire field of surgery. What would become of general surgery if the head, spine, and peripheral nerves were lopped off by the neurosurgeons; if the specialists in thoracic surgery took over the chest; if the urologist took over the genito-urinary organs; proctologists, the rectum and colon; orthopaedic surgeons, fractures and dislocations and the extremities; and plastic and oral surgeons appropriated their own special field? The gynecologists and obstetricians have for a long time claimed the female genito-urinary tract as exclusively their own. This would leave to general surgery nothing except that small part of the body between the diaphragm and the umbilicus; and now comes another claimant into the field, the tumor specialist or the cancer specialist. I have no hesitation in denouncing this last as a very serious blunder. We might just as well develop specialists in inflammation of all parts of the body as to train men as specialists in cancer involving all parts of the body."

One point that we must always remember is that specialization has led to an increased amount of research; in fact, specialization many times implies special investigation and

survey of the venous system and its circulation. The problems of differential diagnosis are discussed, as well as the various methods of localizing disorders of the veins. In a third section, the previous methods of treatment, which were so often unsuccessful, are described, in order to show the evolution of the methods now being used.

This book should be of interest and value to those surgeons with a reading knowledge of Spanish.

THE HEAD, NECK AND TRUNK. MUSCLES AND MOTOR POINTS. Daniel P. Quiring, Ph.D. Philadelphia, Lea and Febiger, 1947. $2.75.

This book portrays in diagrammatic form the muscles of the head, neck, and trunk, and is intended as a companion volume to *The Extremities*, published by Quiring and his co-workers in 1945. In most instances the muscle and a brief statement of its origin, insertion, function, and the nerve and artery which supply it are included in a single diagram, based upon original dissections and upon references to Gray's *Anatomy* and Cunningham's *Text-Book of Anatomy*.

Thus this book, like the previous volume, provides a source of reference by which the anatomy of muscles may be reviewed rapidly and accurately.

THE CHALLENGE OF POLIO. THE CRUSADE AGAINST INFANTILE PARALYSIS. Roland H. Berg. New York, The Dial Press, 1946. $2.50.

The author has termed this book "the biography of a disease". It is really a report to the shareholders, the people of this country, who have contributed millions of dollars—much of it in dimes—for the care of those stricken with poliomyelitis; and, more important still, for the study of the disease,—its etiology, its method of attack, its prevention and cure. In terms for the layman, Mr. Berg makes this "report to the nation". He evaluates the results of research and states the understanding of the disease to this point.

MEDICINE IN THE CHANGING ORDER. REPORT OF THE NEW YORK ACADEMY OF MEDICINE COMMITTEE ON MEDICINE AND THE CHANGING ORDER. New York, The Commonwealth Fund, 1947. $2.00.

This book of 258 pages represents still another in the series of reports by the New York Academy of Medicine Committee on Medicine and the Changing Order. It does not pretend to answer the vital question of how more adequate medical care can be made available to more of the people; but it does attempt a survey of the present health of the nation, and an analysis of the quality and quantity of available medical services. In addition, it provides the reader with current background by its discussion of such questions as medical care in urban and rural areas, public health services, preventive medicine, hospital facilities, and so on.

As a logical development of the subject, it sums up the more important recommendations of the Committee with respect to methods for improvement of existing conditions.

When one considers that the United States, now at the very apex of its political and economic power, lags behind other nations in providing adequate medical care to all, one quickly becomes aware of the urgency of the problem, and the necessity of choosing from among the many projected solutions, the one which will bring most general satisfaction. It will be a difficult decision, for, in recent years, no other question has been the cause of such heated debate among members of the medical profession.

DIE TECHNIK DER KNOCHENBRUCHBEHANDLUNG IM FRIEDEN UND IM KRIEGE. 5 bis 8 Auflage, Band III, Die Marknagelung nach Küntscher. Dr. Lorenz Böhler. Wien, Wilhelm Maudrich, 1944. $5.25.

With each revision of Dr. Böhler's textbook on treatment of fractures, so much new material is added that the volume becomes larger and larger. This present book (the third volume of the eleventh edition) covers only one portion of the subjects treated in the previous volumes, but this portion is greatly expanded.

The larger part of the book is devoted to an exposition of medullary nailing of fractures, according to the method of Küntscher. The application of the method, with certain modifications, to the various long bones is discussed in detail and fully illustrated.

In this revision, later results in some of the 500 cases cited in earlier editions are reported. These end results, as well as nearly 100 more recent cases included in this new edition, have shown a series of unexpected late complications, such as an osteomyelitis which has become apparent as much as a year after the removal of the medullary pin, and the development of pseudarthrosis after apparent bony union has taken place.

As the result of his broader experience, the author considers the closed medullary pinning the operation of choice in simple fractures of the femur, in severely displaced simple transverse fractures of the tibia and of the humerus, and in exceptional cases of forearm-shaft fractures. He feels that open medullary nailing should be used in fresh compound fractures of the femur, but is contra-indicated in fresh fractures of the tibia and of the forearm.

The information received shows conclusively that the treatment of injuries, infections, and tumors of the bones and joints, which has been a matter of controversy between the two services, has finally become the province of the orthopaedic surgeon. The treatment of amputations is rather evenly divided; but, because of the importance of preventing deformity of the joints, a problem in all amputations, and of the need for the development of prostheses both temporary and permanent, so vital to the patient's best interest, I would venture to predict that all amputations will ultimately come under the supervision of orthopaedic surgeons.

The responses to the questionnaires show that a majority of the schools have separate divisions of neurosurgery, orthopaedic surgery, genito-urinary surgery, obstetrics, and gynecology; but, in some cases, they do not have special divisions of thoracic surgery, plastic surgery, vascular surgery, surgery of the hand, and proctology,—this is particularly true of the last two branches.

In about two-thirds of our medical schools, in addition to surgery of the abdomen and neck and the teaching of the fundamentals of surgery, the general surgeon still does some thoracic surgery, rectal surgery, common skin grafts, treatment of infections of the hand, and of vascular conditions, including treatment of varicose veins and ligations for thrombosis.

In 63 per cent., the orthopaedic surgeon teaches the fundamentals of surgery—such as wound healing, sepsis, trauma, shock, and hemorrhage—in relation to his own special field. The number of hours given to the teaching of orthopaedic surgery is agreed upon in a majority of the schools by the professor of orthopaedic surgery and the professor of surgery. In other schools, this decision is made by a special faculty committee or a regular ommittee on the curriculum. In about one-half of the schools, the teaching of orthopaedic surgery is a postgraduate subject. In approximately 40 per cent., the head of the department of orthopaedic surgery has some voice in the selection of interns; and in 48 per cent., he is consulted in the choice of assistant residents in surgery.

In answer to the question: "*Should The American Board of Orthopaedic Surgery decide to require an additional year of training in surgery as a requisite to formal training in orthopaedic surgery, do you believe that the department of surgery in your medical school will cooperate in the matter of providing assistant residencies in surgery?*"—there were thirty-two replies in the affirmative and six in the negative.

To the question: "*Would men desiring to train in orthopaedic surgery have equal opportunity to secure residencies in surgery with men desiring to train in general surgery?*"—out of a total of forty-three schools, thirty-one replied in the affirmative and twelve in the negative.

To the question: "*As a rule would preference be given to men desiring to train in general surgery?*"—out of thirty-nine schools, eighteen replied in the affirmative and twenty-one in the negative.

I am inclined to believe that some of these replies may be in the nature of personal impressions, rather than the result of reflection or careful inquiry.

Now that The American Board of Orthopaedic Surgery has announced officially that it will require an additional year of training in surgery, I consider it a matter of vital importance to determine immediately whether the medical schools will cooperate in providing the necessary residencies for students in orthopaedics on an equal footing with postgraduate students in other branches of surgery. I think we should insist upon this. After all, equality of opportunity is one of the cardinal principles of a democracy.

In reply to the question: "*Do you have facilities for complete training in orthopaedic surgery, including fractures, children's orthopaedic surgery, and fundamental sciences?*"—forty-one indicated that they had all the necessary facilities and ten were lacking in some particulars.

The question, "*Do your facilities for training in orthopaedic surgery include emergency*

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The Journal of Bone and Joint Surgery

EDITORIAL ANNOUNCEMENT

Beginning in January 1948, the scope of *The Journal of Bone and Joint Surgery* will be extended. Surgeons throughout the English-reading world will be able to keep in closer contact with each other's work in orthopaedic surgery through a single, jointly edited and administered journal. They will find recorded on the pages of their *Journal*, the progress and trends in orthopaedics, not only in their own, but in other countries.

Techniques, fundamental clinical studies, and advance in the basic sciences will be recorded from a wider circle of contributors, of more diverse background, than heretofore. These articles will appear not alone as contributions to world orthopaedic surgery; national individuality will be retained.

The American Orthopaedic Association, in conjunction with The British Orthopaedic Association and The American Academy of Orthopaedic Surgeons, sponsor this extension of the scope of *The Journal*.

The British Editorial Board under the auspices of The British Orthopaedic Association will be representative of orthopaedic surgery throughout the British Commonwealth of Nations. The British Editor is Sir Reginald Watson-Jones.

As representative of orthopaedic surgery in the United States of America, the American Editorial Board will be appointed from the membership of The American Orthopaedic Association and the fellowship of The American Academy of Orthopaedic Surgeons.

The American and the British Editorial Boards will be enlarged to a membership of sixteen each. More adequate representation, geographically, becomes possible on the larger Boards. Wider diversity of attainment and discipline, as well as the viewpoints of younger men, will be needed in shaping the future work of *The Journal*. Through more representative Boards, these needs may be met. Collaboration in the broader aspects of policy and correlation of activities of the two Boards will be possible through joint meetings.

The Journal, at present a quarterly, will be published in eight issues. In this larger *Journal* there will be increased space for the publication of significant articles. Four of the eight numbers will be edited and published in Great Britain (the British Volume), and four in the United States of America (the American Volume). Through separate volumes, postal regulations can be met.

Issues of the United States and of the British Commonwealth will appear alternately, at six-week intervals throughout the year, and will be mailed directly to the subscriber from the respective offices of publication.

The subscription price of the two volumes will be \$14.00 or £3.10.0, postage prepaid.

Articles submitted for publication from all nations will, as heretofore, be welcome. Such articles are earnestly solicited, and may be submitted to either the American or the British Editorial offices of *The Journal*.

William A. Rogers, *Editor*

in surgery is always to be found in the ranks of the *soi-disant* general surgeons. In the past this may have been true, but in these days the belief that the general surgeon possesses the automatic and inalienable right to acquire the chair of surgery is out of date. As Platt points out, he is now only one among many in his capacity to contribute to techniques and fundamental knowledge.

In discussing the surgical picture with Dr. John Saunders, Professor of Anatomy in the University of California Medical School, whose contributions are known to all of you and who has been an invaluable aid to me in the development of the teaching of orthopaedic surgery, he made the following excellent analysis of the situation: "If we believe that the so-called general surgeon is in reality a specialist in abdominal surgery, then his activities must be grouped with those of other specialties. This leaves behind an area of common interest,—an area which comprises the fundamental principles of surgery and its basic elements. All surgeons possess a common interest in this field, to which they all contribute and where they may serve as a mental stimulus to one another. Furthermore, it is here that the important liaisons with the basic sciences should be established. Therefore the term 'general surgery' still possesses utility, but only when applied to a field which is general to all surgeons."

My first recommendation for future development would be that orthopaedic surgery should secure full recognition in our medical schools as a major department of surgery, with its own budget, the right to select members of its staff, control promotions, and be responsible only to the dean and to the executive faculty. This is, however, a general statement, as existing conditions in each school should determine the course of action. Every division of orthopaedic surgery must stand on its own merits, but my own observation and many discussions with leaders in various branches of surgery, together with a study of the responses to the questionnaires which I have cited, lead me to believe that the departments of orthopaedic surgery in most of our medical schools deserve the status of major departments.

Granted we are given our place in the sun, what should be our future course of action? I believe that we should do everything possible to promote integration in our department of surgery. Integration with the authority of a major division in surgery is quite a different matter from working under the handicap of the status of a subdepartment with little or no final authority. And with the power of autonomy, we must integrate the teaching of surgery from the broadest possible angle, in order to enable the undergraduate to secure a correct perspective. I believe that we should assume an active role in the teaching of general principles of surgery as a whole, as well as their application to our particular field. As Carl Badgley, my former associate at the University of Michigan, so well expressed it—"Our aim should be first to train doctors, second to train surgeons, and then to train orthopaedic surgeons". This would give us an opportunity to disabuse the minds of students of prevailing misconceptions as to the limited scope of orthopaedics. We should no longer be the stepchild in surgery. In the teaching of postgraduates and for the enhancement of our own knowledge and breadth of outlook, we need intimate contact with men in other branches of surgery. Specialists in the same surgical field are not for long the best company for each other. The stimulating effect of close association with men in the other surgical divisions is indispensable to our future development. In our modern medical schools, surgical rounds should be, in a certain sense, a kind of forum where student, intern, resident, and visiting staff could see surgery in its true perspective and evaluate the contribution of each branch. These forums would be invaluable in solving our common problems, particularly in fields of surgery which overlap. For example, consider the untold benefits which would result from a combined study by the neurosurgeon and the orthopaedic surgeon of every phase of treatment in cases of suspected lesions of the intervertebral disc. And what good results would ensue from a combined study by the neurosurgeon, genito-urinary surgeon, and the orthopaedic surgeon of paralytic lesions arising

its humble beginnings up to its present highly developed skill. One of the great masters of surgery, Sir Robert Jones, has defined orthopaedics in the following terms: "The treatment by manipulation, operation, re-education, and rehabilitation of the injuries and diseases of the locomotor system". This comprehensive definition of the scope of orthopaedics is a far cry from the modest efforts of the early bone-setters, and it serves to emphasize the infinite possibilities of modern orthopaedic surgery.

Although the Frenchman, André, as early as 1741, defined the term "*orthopaedia*" as the art of preventing and correcting deformities in children, orthopaedics was not taught as a specialty until 1887, and its modern development can be traced to the foundation of The American Orthopaedic Association. For the first fifteen years of its existence as a special field, our activities were confined largely to the use of mechanical appliances, and our contemporaries in other medical branches referred to us as "the buckle-and-strap men". Willard, in his Presidential Address of 1935 before this Association, speaks of this period of the treatment of deformity by mechanical means. He further states that, in the Annual Meeting of 1893, only one paper out of thirty-one dealt with surgical procedures, and even such subjects as "A New Method of Curing Soft Corns" and "The Mechanical Treatment of Ingrown Toenails" were discussed by eminent men.

Previous to 1900, the only major surgery advocated was destructive in character, excision of the hip for tuberculosis being frequently mentioned. With the turn of the century, however, more constructive types of operation were developed, and operative correction of deformity arising from a variety of conditions became more general. Brackett, in 1905, pointed to the enlarged scope of orthopaedic surgery, which had then come to include the treatment of adults as well as of children. These advances in orthopaedic surgery have kept pace with modern surgical advances in other branches. In 1911, Albee introduced the use of the bone graft in the treatment of tuberculosis of the spine, and during the next few years extended its application to include ununited and malunited fractures. During this same period, Gallie and Phemister did their pioneer experimental work with bone grafts, which added to our fundamental knowledge of how results were obtained. Gallie demonstrated his work at the Massachusetts General Hospital in Boston in 1915, when Smith-Petersen and I were serving as house officers on the Orthopaedic Service. Our chief was Dr. Elliott Brackett, a splendid surgeon, while the assistant chief was Dr. Robert Osgood, a great teacher and inspiring leader. Among many operations performed by them were fusions of the spine and of the joints in tuberculous conditions, the application of bone grafts in ununited fractures, arthrodesis of the hip for arthritis, tendon transplantations, and a variety of operations for infantile and spastic paralysis. The effect of faulty posture in the production of back strain, particularly of the lumbosacral and sacro-iliac joints, was demonstrated by Goldthwait. Various deformities resulting from arthritis were corrected in the orthopaedic wards. But fresh fractures were considered as solely within the province of the general surgeon, who exercised every precaution to prevent the orthopaedic surgeon from taking part in their treatment, unless complications arose,—such as malunion or non-union. I well remember the critical attitude assumed by one of the senior members of the general surgical staff, because a fracture of the neck of the femur had been treated on the Orthopaedic Service, when he felt that a state of non-union had not yet developed. It was on this case and several others following that Brackett developed the now well-known "Brackett operation" for non-union in fractures of the neck of the femur. About this time, my valued friend, Smith-Petersen, because of his dissatisfaction with the methods of exposure then employed, developed his approaches to the hip and the sacro-iliac joint. These were the first of many original contributions made by him.

During World War I, great strides were made in orthopaedic surgery. It was my good fortune to witness these at close range, having been sent to Great Britain as one of the first twenty orthopaedic surgeons who served under the Military Director of Orthopaedic

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ARTHRODESIS OF THE ELBOW

A Preliminary Report of a New Operation*

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Although it is generally agreed that the indications for arthrodesis of the elbow are few, a rather imposing number of procedures for the purpose of fusing this joint have been described [1,3,6,7,8,9,10,11].

The object of this paper is not to discuss the merits of arthrodesis, as compared with excision [2,4,5] of the elbow, but to propose an additional method of fusion, which may be useful in certain cases, especially in tuberculosis, where the orthopaedic surgeon feels that the circumstances justify the employment of this form of treatment.

The procedure is not too formidable. It brings relatively uninvolved bone surfaces into intimate contact. The graft is easily and firmly anchored. Bone from other sources is not needed, and material for bone pegs or chips is readily available. The radiohumeral joint is not disturbed, which allows for the possible retention of rotation of the forearm. The elbow joint may be placed at any desired angle without additional operative modification.

DESCRIPTION OF THE OPERATION

An incision is made on the inner aspect of the elbow from five centimeters above to five centimeters below the tip of the medial epicondyle of the humerus. The ulnar nerve is isolated and is freed sufficiently to permit careful retraction from the operative field.

*Presented before the Orthopaedic Section of the Baltimore City Medical Society, Baltimore, Maryland, April 28, 1947.

Later in the War at Savenay, a collecting base for evacuation to this country, the same conditions prevailed, but on a larger scale. Compounded fractures were treated inadequately, and the fundamental principles that we had used in England were not generally applied. However, under the dynamic leadership of Colonel Goldthwait, the necessary changes were rapidly made. Men with fractures were placed on the Orthopaedic Service, where the treatment consisted in the application of adequate splinting and immobilization, the institution of proper dependent drainage, and the meticulous care of the wound. They were cared for in special wards, depending on the anatomical location of the injury. Patients with amputation stumps were also segregated, and nearly all of these amputations were of the guillotine type. They were treated by splinting and traction to prevent deformity of the adjacent joints, and in order to gradually pull the skin over the end of the stump. Early ambulation with temporary prosthesis was also used effectively. I was greatly impressed by the amazing results accomplished through the universal application of these simple fundamental principles of orthopaedic surgery.

My third year of experience and observation abroad was not spent in Army hospitals, as I returned to Edinburgh for further training in general surgery under my former chief, Sir Harold Stiles. For the first six months, my assignment was that of Resident-Surgeon at Chalmers Hospital and assistant to Sir Harold in his private practice. During the latter part of my stay I was Resident-Surgeon in the Royal Infirmary under Sir Harold, who had then been appointed Regius Professor of Clinical Surgery, a post formerly held by such illustrious men as Syme, Annandale, and Lister. In the Royal Infirmary, our wards were filled with all types of cases and general surgery was *actually general*, because specialization was practically non-existent. Our operations included the fields of neurosurgery, chest surgery, genito-urinary surgery, orthopaedic surgery, and surgery of the abdomen and neck. Sir Harold foresaw the inevitable necessity for specialization, because of the rapid developments in surgery, and he insisted on the need for placing the treatment of fractures on a different basis. Our wards were the first to possess adequate equipment, including splints, overhead frames, and fracture tables, for modern orthopaedic treatment. The use of plaster-of-Paris and the technique of its application were introduced in these wards, and I often smile when I recall the reproachful remarks of Mr. Alexander, the keeper of supplies, when he accused me of using more plaster-of-Paris in six months than had been used in the Royal Infirmary during the previous thirty years. This period was really the beginning of the evolution of modern orthopaedic surgery in the Royal Infirmary of Edinburgh. Sir Harold Stiles immediately perceived the significance of this trend in surgery; and, upon his insistence, a lectureship in orthopaedics was established in the University of Edinburgh Medical School.

Following World War I, a number of younger general surgeons who had done some orthopaedic work in Europe during the War decided to specialize in orthopaedics and devoted considerable time to further training when they returned to this country. These men have made fine contributions, both in the laboratory and in clinics. With the increase in the scope of orthopaedic surgery, many able men have been attracted to it. In 1933, The American Academy of Orthopaedic Surgeons was established to provide a forum where they could discuss their common problems and maintain first-hand contact with the developments that were being made. The Academy has done much to promote the advance of orthopaedic surgery by its scientific programs, instructional courses, and technical and scientific exhibits.

In addition, The American Board of Orthopaedic Surgery was created in 1934 for the purpose of elevating the standards of orthopaedic training and the qualifications for practice. With the advent of World War II, the orthopaedic surgeon came into his own in the care of injuries and infections of the bones and joints. Moreover, the treatment of amputations was assigned to him in specially organized amputation centers.

At the present time, our field has become so extensive that, as stated by Gill in his

is changed, the protruding wires, if used, are removed. The cast is renewed at suitable intervals, until fusion of the elbow joint is demonstrated clinically and by roentgenogram.

CASE REPORT

W. S., a thirteen-year-old colored boy, was admitted to the Kernan Hospital on March 22, 1946, complaining of a swollen and painful right elbow, following injuries sustained in December 1945 and February 1946. The family history revealed that the patient's father had tuberculosis. The joint fluid was aspirated on several occasions. Smear, culture, and guinea-pig inoculation of the joint fluid were negative, but sinuses developed at the sites of the aspirations and remained open. The patch test was strongly positive for tuberculosis. In spite of immobilization by casts, the elbow remained swollen and thickened; the sinuses continued to discharge purulent material; and the roentgenograms demonstrated a progressive deterioration of the joint. Although as yet there were no laboratory evidences of tuberculosis, the entire clinical picture led to this diagnosis.

Accordingly, the described operation, which had been conceived several years before, was performed on May 17, 1946. When the first cast was removed on August 2, 1946, approximately twelve weeks from the date of operation, the elbow had fused. The wires were removed on September 13, 1946. During this procedure, the graft was found to be firmly united to the humerus and the ulna. Granulation tissue, curretted from the sinuses, was reported by the pathologist as tuberculous. The elbow has thus far remained solid, many months after removal of all support; this fusion is confirmed by the roentgenograms. An ulnar palsy, which followed the operation, has gradually cleared, but sêveral sinuses are still draining.

NOTE: Since this paper was written, a similar condition seems to have developed in the opposite elbow. The biopsy report of sections from the glands of each axilla was "tuberculous adenitis".

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we all acknowledge our indebtedness to research in its advancement of medical knowledge. But in the words of Daniel Fiske Jones, "specialization has robbed the general surgical service to such an extent that it really does not exist".

Nevertheless, some of the leaders in surgery today recognize and approve the evolutionary trend as, for example, Coller in the following statement: "True specialization is a striving for perfection and we owe a great debt to those who have by their efforts in limited fields so greatly enhanced our knowledge as a whole".

Wangensteen, too, in an article entitled, "The Surgeon and His Trust", sets forth some pertinent facts of great interest. He states: "There are still a few surgeons who affect to believe that they can take all of surgery for their province. They know as well as any one that their performance in such a wide category of operative procedures is substandard in some of these areas when judged in the critical light of what constitutes good practice. In our time we have seen the province of the general surgeon shrink so much that occasionally we wonder what areas of surgery are embraced in the designation general surgery. Yet this is as it should be. If a teacher of surgery were so ardent a student in his art that he wished to encompass the entire field, an aspiration more ambitious than praiseworthy, he would remain all of his days a learner and would thereby lose the important opportunity to give directional growth to a small sphere of surgery. Teachers of surgery must prove themselves in the next generation as well as in this. The teacher who leaves no intellectual progeny has not been fully alive to his responsibilities nor wholly faithful to his trust." Wangensteen concludes: "Let us be thankful that the day of the all-around surgical specialist is done! Surgery is not advanced by that type of activity, and no matter how talented the surgeon, he cannot do equally as good work in all these provinces.

"The background of training of the surgeon should be broad. But having acquired orientation and competence, a surgeon must of necessity, if he aspires to rise above mediocrity, give selective direction to his activity instead of trying to grow in all directions simultaneously."

For the purpose of securing data concerning the present status of orthopaedic surgery in our medical schools, I sent questionnaires to the heads of the orthopaedic departments. They all responded promptly, and I made an analysis of the information secured from fifty-three schools. Of these, seventeen have major departments of orthopaedic surgery,—that is, departments which have a certain measure of control over the amount and distribution of the budgets, appointments and promotions on their staffs, and representation on the executive advisory committees of the deans of their respective schools. Thirty-six are subdepartments in surgery, but of these, eleven have appointments on the deans' committees; that is, in approximately one-third of our medical schools the orthopaedic divisions have autonomy. Some of these major divisions, however, apparently are inadequately financed. In 70 per cent. of the schools, fractures, osteomyelitis, joint infections, and bone tumors are treated exclusively on the orthopaedic service. In the remaining schools, the treatment of these conditions is divided between orthopaedic surgery and general surgery, while in a very small percentage they are treated solely on the surgical service. In 20 per cent., amputations are cared for exclusively on the orthopaedic service; in 8 per cent., they are treated on the surgical service; and in 72 per cent., the treatment is divided between the two services. Acute surgery of tendons is performed on the orthopaedic service in 23 per cent. of the schools, on the surgical service in 34 per cent.; and in 43 per cent. it is divided between the two. Treatment of infections of the hand is assigned to the orthopaedic service in 16 per cent., to the surgical service in 22 per cent., and to both services in 62 per cent. Teaching of the subjects of fractures, osteomyelitis, joint infections, bone tumors, amputations, and surgery of the tendons and of the hand is divided between the two divisions of surgery in about the same proportion as the treatment of these conditions, with a slight margin indicated in the interest shown in these studies by the division of surgery.

The animals received roentgen irradiation* [1] through a 4-by-5-centimeter portal over the left foreleg at the radiocarpal joint, and over the right hind leg at the tibiofemoral joint. There was one exception to this plan of treatment. The left elbow of Dog No. 1 was treated instead of the left wrist. The portal covered the joint, the epiphyses, and the adjacent metaphyses. Dosages were given at a single sitting in equal amounts to one foreleg and one hind leg of each animal. One-half the dose was given through an anteroposterior portal and the other half through a postero-anterior portal. The dogs were divided into three groups (A, B, and C) of four each (two from each litter). Group A received 800 r; Group B, 1,000 r; and Group C, 1,200 r. The animals were sacrificed at intervals varying between four and twenty-four months, as shown in Table I.

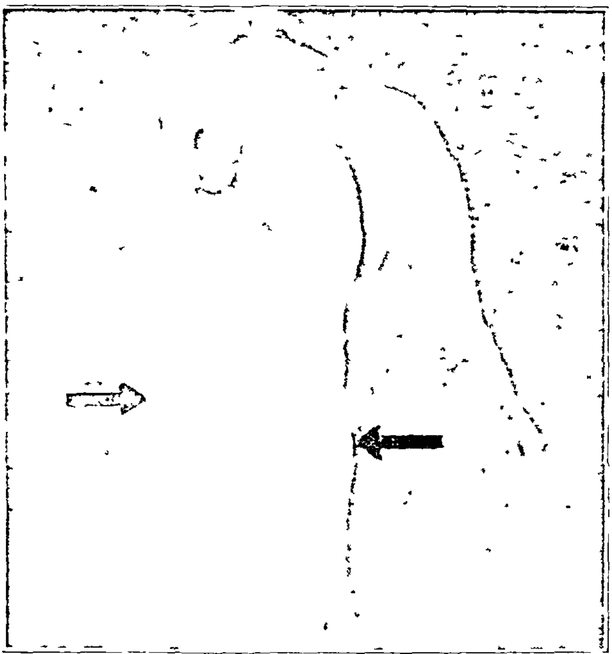

FIG. 1-A

FIG. 1-B

Fig. 1-A: Photograph of Dog No. 9, showing shortening of treated left fore limb.
Fig. 1-B: Photograph of Dog No. 3, showing shortening and bowing of treated left fore limb. This animal showed the greatest deformity of any of the dogs.

Seven weeks after treatment had been given, small metallic markers were inserted into the diaphysis of each tibia and radius, at approximately the mid-shaft. This made it possible to determine by roentgenography the proportion of growth contributed by the distal and by the proximal epiphyses of these bones.

Teleoroentgenograms were made at the outset of the experiment and were repeated at intervals of approximately six weeks through the fortieth week, when the epiphyses were found to be fused and growth was essentially at a standstill. Thereafter, roentgenograms were made at various intervals, the final one just prior to sacrifice of each animal.

At the time of sacrifice, gross examination of both the treated and untreated members was carried out. Particular attention was directed to the tissues subjected to irradiation, and to their counterparts. Sections of skin, muscle, and other soft tissues, and of metaphyses, epiphyses, and articular surfaces of the lower portion of the radius, ulna, and femur, of the upper portion of the tibia, and of the patella and the carpal bones were taken from both sides for microscopic examination.

All tissues were fixed in 10 per cent. formalin. The bones, after fixation, were decalcified in a 5 per cent. aqueous solution of nitric acid. Sections were cut in colloidin and stained with hematoxylin and eosin.

* The source of irradiation was a roentgen-ray machine with the following factors: 200 kilovolt peak, 20 milliamperes, 50 centimeters target-skin distance, filtration of 0.5 millimeter of copper and 1.0 millimeter of aluminum. The half-value layer was 1.0 millimeter of copper. The rate of delivery was 38.5 r per minute.

surgery, enabling your residents to treat emergency cases in their own field and also to observe emergencies in other fields of surgery, such as head injuries, acute abdomens, etc.?"—brought forty-six affirmative replies and four negatives. The necessity for this experience is an integral part of the broad general training which I consider has not been sufficiently emphasized.

To the question: "*In the history of your school has the professor of surgery been selected from any field other than general surgery?*"—forty-one answers were in the negative and ten in the affirmative. Of these ten, there were six neurosurgeons, two thoracic surgeons, and one whose chief interest was vascular surgery. There was none among the number who bore the title of orthopaedic surgeon.

To the question: "*If you could participate on an equal basis with men in other special fields of surgery, including the so-called general surgery, in decisions as to teaching programs, distribution of funds for the budget and the general management of the surgical department, would you, in your opinion, serve the best interests of the patient as well as the student, and promote the advancement of orthopaedic surgery as the head of a subdepartment of surgery or the head of a completely independent department of orthopaedic surgery?*"—seventeen out of forty-nine stated that they would prefer to be heads of subdepartments and thirty-two preferred major status. In other words, the proportion is two to one in favor of making orthopaedic surgery a major division, on an equal footing with other divisions of surgery.

In this paper, I have endeavored to describe the progress of orthopaedic surgery from its embryonic stage in the latter part of the Nineteenth Century up to its present maturity. Today, we are fulfilling the destiny predicted in the definition of orthopaedics by that great leader, Sir Robert Jones. We are both physicians and surgeons whose ultimate purpose is to restore, by manipulation, operation, re-education, and rehabilitation maximum function of parts affected by injuries and diseases of the locomotor system. Orthopaedic surgery of today covers the field of general surgery of yesterday. The so-called general surgery is a remnant from the past, because, as we all know, in the course of the development of surgery as a whole, many branches have split from the parent stem. These changes in surgery parallel changes in other fields of endeavor and are a part of the natural process of evolution and the mutations of progress. Of these special branches which have been developed, orthopaedics represents the largest single abstraction from the general field of surgery. The breadth of its scope and the broad field that it covers in the anatomy of the human body entitle it to an equal place in surgical teaching with any other division of surgery. Yet, the departments of orthopaedic surgery in the majority of our medical schools are still classified as subdepartments, and they have not acquired the autonomy to which they are entitled.

In our modern medical schools, the expression "general surgery" is used to designate the group of surgeons who, in the past, were general surgeons, but who now confine their major activities to surgery of the abdomen and neck. The term "general surgeon" is a misnomer; and at the present time it would be an anachronism for any surgeon to claim to cover the entire field of surgery. The continued use of the term is harmful in a number of ways in the development of surgery in our medical schools. It conveys to the mind of the student the idea that he is being taught the science of surgery as applied to the entire body, which is entirely erroneous. Because of the undue emphasis which is placed on abdominal surgery, the student inevitably gets a false perspective. One of the harmful results of this system is that the undergraduate regards orthopaedic surgery as relatively unimportant and a subject to be considered for postgraduate work. The magic words "general surgery" undoubtedly influence the future of many undergraduate students, particularly those who wish to excel. This prevents orthopaedic surgery from getting a just proportion of the high-class men who are material for future leaders and teachers. Moreover, the title "general surgeon" conveys to the minds of the deans and members of the executive faculties of our medical schools the impression that all-round ability

TABLE VI

GROWTH FROM PROXIMAL AND DISTAL EPIPHYSES OF THE UNTREATED TIBIA AND RADIUS

Group	No. of Dog	Tibia				Radius			
		Proximal Epiphysis		Distal Epiphysis		Proximal Epiphysis		Distal Epiphysis	
		(Centimeters)	(Per Cent.)	(Centimeters)	(Per Cent.)	(Centimeters)	(Per Cent.)	(Centimeters)	(Per Cent.)
A	5	2.9	51	2.8	49	1 9	35	3.6	65
A	6	3.2	52	3.0	48	2.2	34	4.2	66
A	11	2.7	49	2.8	51	1.8	33	3.6	67
A	12	1.8	51	1.7	49	1.2	34	2.3	66
Averages			51		49		34		66
B	3	2.5	50	2.5	50	1.6	30	3.7	70
B	4	3.4	51	3.3	49	2.2	35	4.1	65
B	9	3.2	52	3.0	48	2.0	36	3.6	64
B	10	2.9	49	3.0	51	1.7	33	3.5	67
Averages			51		49		34		67
C	1	2.8	52	2.6	48	1.9	35	3.6	65
C	2	2.7	52	2.5	48	1.8	33	3.6	67
C	7	2.8	52	2.6	48	1.9	36	3.4	64
C	8	1.8	49	1.9	51	1.6	41	2.3	59
Averages			51		49		36		64

from injuries to the spinal cord! As my friend, Fred Coller, says: "What we should strive for is not to make everyone a general surgeon, but to make all who practice in any surgical field 'Generals in Surgery'", and Harry Platt, in the London *Lancet*, admirably sums up the goal we are seeking in these words: "If we aim at the highest standards for the future, we shall ensure that the orthopaedic surgeon will be among the best educated of the corps of consultants and specialists. It is the duty and responsibility of those entrusted with the training of the orthopaedic surgeon of the future to ensure that we recruit and educate as high a proportion of scholars and teachers as any other of the major specialisms in medicine and surgery. For in the world of medical science, as in society, we shall be ultimately judged by the quality of our contributions to the advancement of knowledge."

I would like to see the department of surgery in our medical schools organized in such a way that the professor of surgery would serve as executive head, with a responsible group of "cabinet officers", consisting of the chiefs of the major divisions in surgery. This group all would contribute to the teaching of fundamentals in the undergraduate schools, so that the students could obtain a true perspective on surgery as a whole. With methods of teaching agreed upon and duplication avoided, it would allow the student more time for practical observation. In addition, the undergraduate should be encouraged to take advantage of broad basic training in surgery before specializing in any particular field. Such a department of surgery would inevitably create an enthusiastic *esprit de corps*, and fine teamwork would be the natural outcome. It would be like a well organized football squad, with no individual stars or prima donnas to unbalance the combined effort of the entire team. This might ultimately develop into a working group similar to the highly successful club which Gallie has promoted in the University of Toronto. The selection of the professor of surgery should not be restricted to any particular field of surgery, but rather the appointment should be made on the basis of scholastic attainments, breadth of background, and demonstrated ability to get along with others. In addition, the head of the department of surgery should possess an unbiased attitude towards the development of all branches of surgery and a discriminating mind which would enable him to recognize exceptional ability in the younger men who are to be the leaders of the future; and, above all, he should have the skill to bridge the gap which too frequently exists between the abstract teaching of basic sciences and their clinical application in wards and laboratories.

These are the high ideals which we should strive to attain. We may not always succeed, but in the words of Robert Browning:

> ". . . a Man's reach should exceed his grasp,
> Or what's a Heaven for?"

Before concluding this paper, I wish to express my deep appreciation to the members of this Association for the great honor they conferred upon me in naming me their President. It is a distinction which I value highly; and, if, during my term of office, I have contributed in some small measure to the recognition of the well-earned right of orthopaedic surgery to enjoy the status of a major department in our medical schools, I shall not have worked in vain.

NOTE: I wish to express my appreciation to Mr. and Mrs. Sidney Ehrman for the sincere interest they have shown in the development of the Department of Orthopaedic Surgery in the University of California Medical School, and to Mrs. Margot Egan, who has been so generous with her time and knowledge in the preparation of this address.

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TABLE VII

EFFECT OF IRRADIATION ON GROWTH OF PROXIMAL PORTION OF TIBIA AND DISTAL PORTION OF RADIUS

Group	Amount of Irradiation	No. of Dog	Growth of Proximal Portion of Tibia				Growth of Distal Portion of Radius			
			Untreated (*Centimeters*)	Treated (*Centimeters*)	Difference (*Centimeters*)	Retarded (*Per Cent.*)	Untreated (*Centimeters*)	Treated (*Centimeters*)	Difference (*Centimeters*)	Retarded (*Per Cent.*)
A	800 r	5	2.9	1.4	1.5	52	3.6	1.8	1.8	50
		6	3.2	1.9	1.3	41	4.2	2.3	1.9	45
		11	2.7	1.7	1.0	37	3.6	1.4	2.2	61
		12	1.8	1.0	0.8	44	2.3	0.9	1.4	61
Averages			2.7	1.5	1.2	44	3.4	1.6	1.8	53
B	1,000 r	3	2.5	1.4	1.1	44	3.7	1.1	2.6	70
		4	3.4	1.7	1.7	50	4.1	2.0	2.1	51
		9	3.2	1.2	2.0	63	3.6	1.0	2.6	72
		10	2.9	1.2	1.7	59	3.5	1.1	2.4	69
Averages			3.0	1.4	1.6	54	3.7	1.3	2.4	65
C	1,200 r	1	2.8	0.8	2.0	71	1.9*	0.3*	1.6*	84*
		2	2.7	0.5	2.2	81	3.6	0.5	3.1	86
		7	2.8	1.0	1.8	64	3.4	1.3	2.1	62
		8	1.8	0.8	1.0	55	2.3	0.6	1.7	74
Averages			2.5	0.8	1.7	68	3.1	0.8	2.3	74

* The proximal radial epiphysis of this dog was treated.

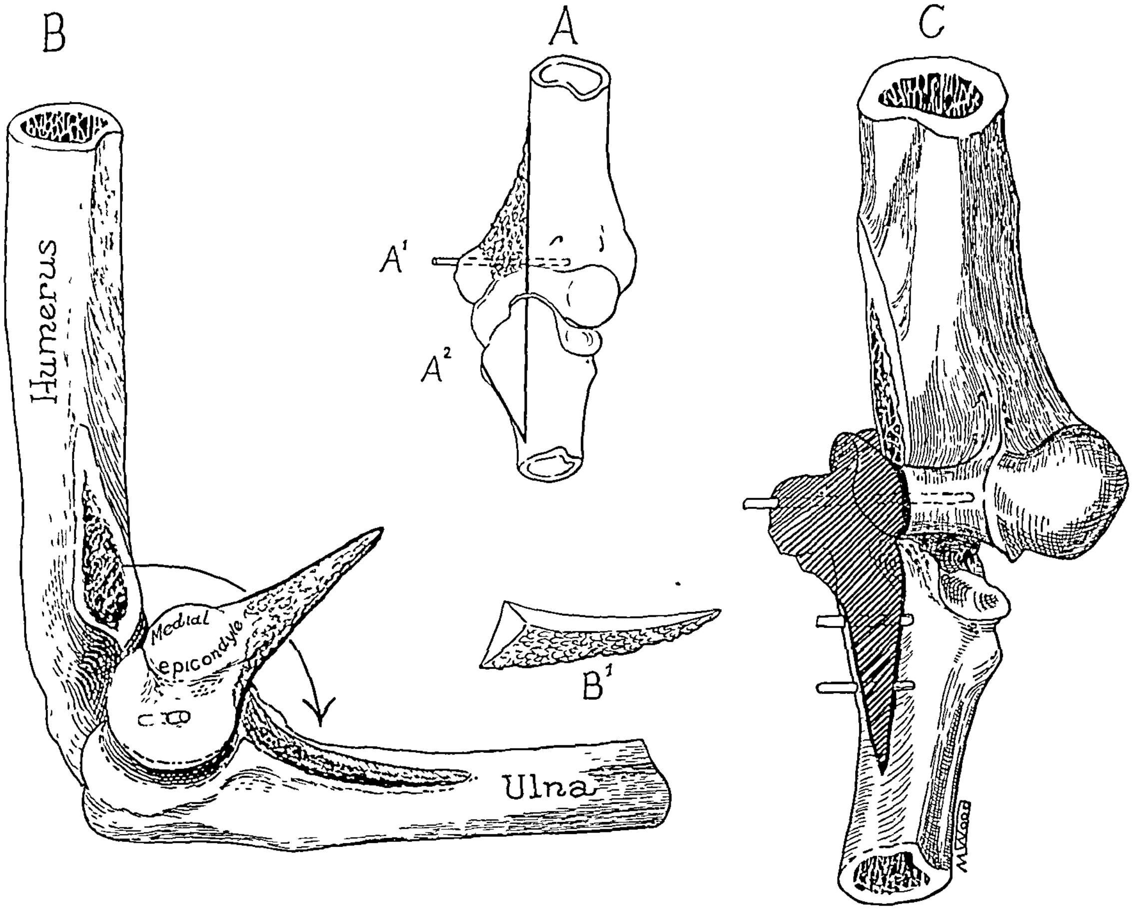


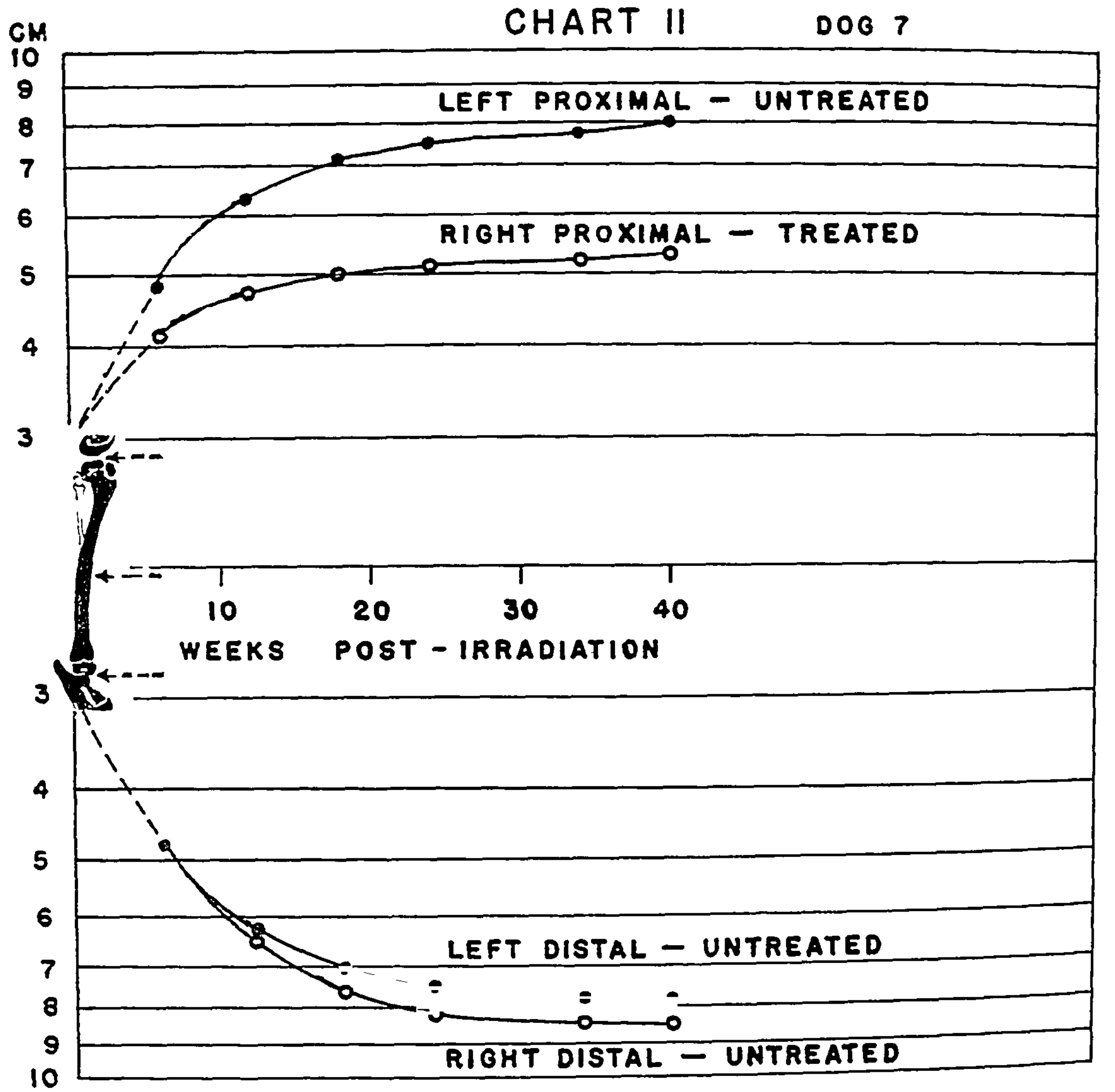
FIG. 1

All of the soft tissues (muscle attachments, periosteum, and capsule) are stripped from the anterior, medial, and posterior surfaces of the medial third of the lower portion of the humerus and from the medial and anterior surfaces of the upper end of the ulna. When this has been accomplished, the medial third of the anterior portion of the exposed humerus, as well as its medial margin, is roughened by the removal of a thin layer of cortical bone (Fig. 1,*A*).

Beginning at the top of the medial supracondylar ridge, approximately the medial third of the lower portion of the humerus is separated with an osteotome, flush with the humeral shaft, and parallel to its long axis (Fig. 1,*A*). When this piece has been freed, a wire, A^1, is passed transversely through the epicondyle and into the humerus to control this loosened mass of bone which will constitute the graft. This graft is then rotated downward until it lies upon the surface of the ulna; an outline of the graft is scratched on the surface of this bone, A^2. The triangular wedge outlined, B^1, is now removed from the anterior cortex of the ulna, and the humeral graft is again rotated downward and fitted snugly into the ulnar trough (Fig. 1,*B* and *C*).

After the most satisfactory angle for the elbow has been decided upon, two additional wires (or screws, or autogenous bone pegs made from the previously removed ulnar wedge) are inserted through the ulna and the transplanted bone to stabilize the graft (Fig. 1,*C*). The wire through the humerus may be removed and replaced by a screw or a bone peg. If it seems advisable, what remains of the triangular ulnar wedge may be converted into bone chips and packed into any crevice that appears to need them. If the ulnar nerve is under any tension, it is transposed anteriorly.

The soft tissues are allowed to fall back into position and are sutured securely, layer by layer. A plaster shoulder spica is applied, and is worn for eight weeks. When this cast



GROWTH OF TIBIAL EPIPHYSES (CM)

compared with the untreated ones. The diameters of the shafts of the bones were diminished approximately 10 per cent.

Roentgenographic evidence in the twelve dogs, including those which had active use of their extremities for the full two years, showed no bone or joint deformity other than a mild bowing which occurred in eight of the treated fore limbs. The joint surfaces were smooth, and the joint spaces were preserved. There were no detectable arthritic changes.

In three animals (two in Group A and one in Group B), roentgenographic evidence of temporary bone resorption in the metaphysis of the treated ulna was found (Fig. 3). This reached its maximum between twelve and eighteen weeks. Healing with remineralization occurred spontaneously (Fig. 2-C). One dog in Group B and one in Group C showed a minor osteolytic focus in the region of the tibial tuberosity at about eighteen weeks, but this had healed in twenty-four weeks.

In summary, the roentgenographic studies have brought out the following points:

1. Marked retardation of longitudinal growth was produced by dosages of roentgen rays ranging from 800 r to 1,200 r, and the retardation was roughly proportional to the x-ray dosages.

2. Minor localized osteolytic or resorptive phenomena which occurred in treated bones were transient, and healed completely.

3. The radius and ulna, treated over their distal epiphyses, showed considerably

THE EFFECT OF ROENTGEN IRRADIATION ON EPIPHYSEAL GROWTH* †

II. Experimental Studies upon the Dog

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Studies previously completed on the young rat [1,3] showed that it was possible to impede growth in the long bones by exposing the epiphyseal cartilages to roentgen-ray irradiation. These investigations demonstrated clearly that, with dosages of between 665 r and 1,165 r (roentgen units), the epiphyseal cartilage was affected profoundly. The adjacent tissues—such as synovial membrane, articular cartilage, cortical bone, bone marrow, and skin—evinced morphological changes of minor import.

To verify the results of the rat experiments and to expand the scope of the animal investigations, it seemed advisable to do a similar study on dogs. These experiments have been undertaken because of their possible therapeutic application to man.

TABLE I

Synopsis of the Experiment

Group	Amount of Irradiation	No. of Dog	Joints Treated	Period after Irradiation before Animal Was Sacrificed (*Months*)
A	800 r	5	Right knee and left wrist	7
		6	Right knee and left wrist	18
		11	Right knee and left wrist	24
		12	Right knee and left wrist	12
B	1,000 r	3	Right knee and left wrist	18
		4	Right knee and left wrist	12
		9	Right knee and left wrist	18
		10	Right knee and left wrist	7
C	1,200 r	1	Right knee and left elbow	12
		2	Right knee and left wrist	24
		7	Right knee and left wrist	24
		8	Right knee and left wrist	4

MATERIALS AND METHODS

Twelve puppies of both sexes were secured,—six from each of two litters of collie mongrels. They were approximately six weeks old at the time the roentgen treatment was given. They were maintained upon a nutritious diet, supplemented by cod-liver oil during the first six months. All were immunized against distemper. The animals were quartered in a large yard, with ample room for exercise. They were not restricted in any unusual manner during the course of the study.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1947.

† Aided by a grant from The National Foundation for Infantile Paralysis, Inc., New York, N. Y.

FIG 4

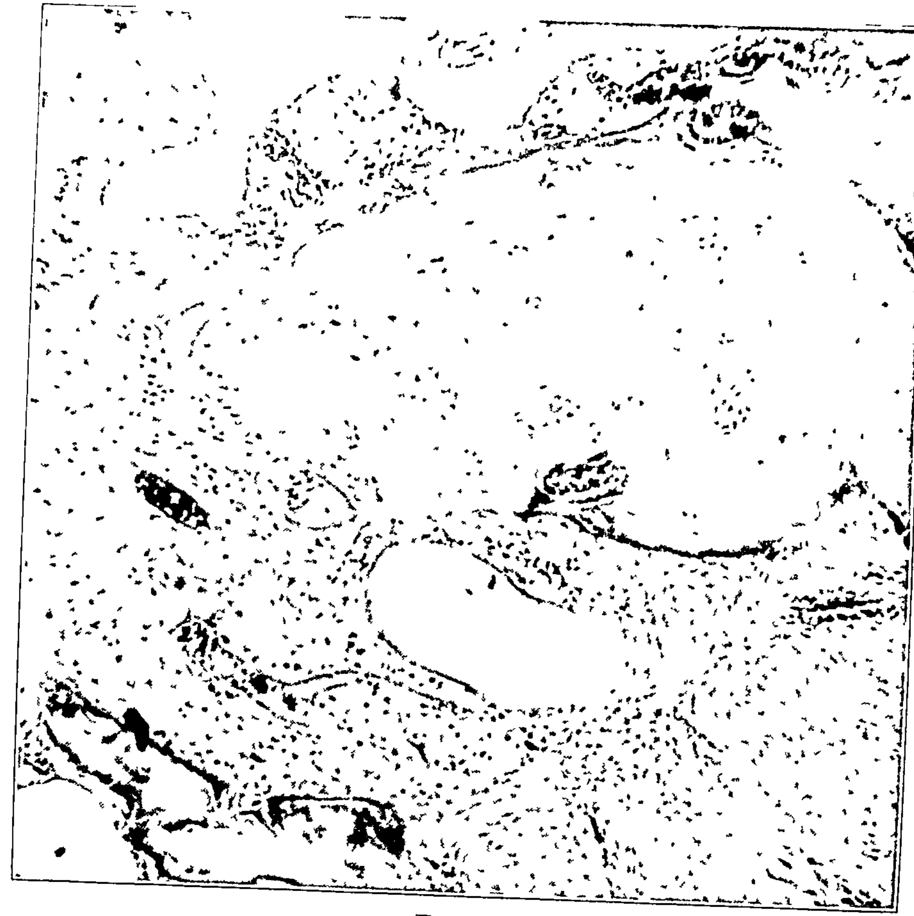


FIG. 5

FIG. 4: Showing regular, elongated, narrow columns of active chondrocytes with uniform mineralization at their metaphyseal ends Included is a segment of the epiphyseal bone plate, containing fatty marrow (× 90)

FIG 5: The cartilage is pale, mottled, and uneven, and the columnar arrangement has been lost. Marrow in both epiphysis and metaphysis is fibrous in character. An irregular plate of bone lies horizontally across the metaphyseal margin Capillaries may be noted, penetrating the degenerated cartilage (× 90).

TABLE II

Total Growth of Tibia and Percentage of Retardation Caused by Treatment

Group	Amount of Irradiation	No. of Dog	Length of Tibia			Retardation (*Per Cent.*)
			Untreated (*Centimeters*)	Treated (*Centimeters*)	Difference (*Centimeters*)	
A	800 r	5	10.8	9.0	1.8	17
		6	11.2	9.5	1.7	15
		11	9 4	8.5	0.9	10
		12	6.6	5.3	1.3	20
B	1,000 r	3	10.4	8.4	2.0	19
		4	12.2	10.3	1.9	16
		9	10.5	8.3	2.2	21
		10	9.9	7.8	2.1	21
C	1,200 r	1	10.8	8.6	2.2	21
		2	10.2	7.4	2.8	28
		7	9.2	7.2	2.0	22
		8	7.8	5.9	1.9	24

OBSERVATIONS

During the experiment the dogs were frolicsome, ate well, and suffered no illnesses of significance. At the conclusion of the study, they seemed entirely normal except for unilateral shortening of limbs, mild bowing of the fore limb in eight animals, and the local coarsening and discoloration of hair. The weight and torso size of the dogs appeared to be unaffected by treatment.

All of the dogs showed retardation of longitudinal growth of the treated extremities

TABLE III

Total Growth of Radius and Percentage of Retardation Caused by Treatment

Group	Amount of Irradiation	No. of Dog	Length of Radius			Retardation (*Per Cent.*)
			Untreated (*Centimeters*)	Treated (*Centimeters*)	Difference (*Centimeters*)	
A	800 r	5	10.3	7.8	2.5	24
		6	11.0	8.6	2.4	22
		11	8.8	6.1	2.7	31
		12	6.3	4.1	2.2	35
B	1,000 r	3	9.9	6.3	3.6	36
		4	11.7	8.6	3.1	26
		9	9.5	5.3	4.2	44
		10	8.9	5.7	3.2	36
C	1,200 r	1	10.4*	8.1	2.3	22
		2	9.8	5.4	4.4	47
		7	8.9	6.2	2.7	30
		8	7.0	4.1	2.9	41

* The proximal epiphysis of the radius (elbow joint) was irradiated in this animal.

lar, fibrillar matrix intervening. The chondrocytes showed degenerative features, varying from swelling to pyknosis and fragmentation. No inflammatory exudate intruded. Penetrating the cartilage plate were occasional capillary channels. There were many widely distributed foci of calcification, dissociated from the normal metaphyseal location. Frequently eosinophilic stripes of partial mineralization extended through the plate, from the bony epiphysis to the metaphyseal marrow. In the zone of new-bone formation, the parallel fragile spicules of calcified cartilage, present in the controls, were replaced by broad, generally horizontally disposed, bony trabeculae, giving clear-cut evidence of cessation of growth. The subepiphyseal marrow contained oedematous, fibrous tissue which was focally myxomatous and lacking in hematopoietic cells. These cells appeared in undiminished numbers and normal proportions in the marrow cavity of the diaphysis. Cortical bone was unaffected. Even those cancellous trabeculae in the subepiphyseal zone of sclerosis exhibited normal intrinsic structure.

There were no stigmata of the extensive degenerative process, just described, in any of the dogs sacrificed after epiphyseal fusion had been completed. In one, a thin horizontal line of cancellous bone marked the site of the resorbed cartilage, but this was also present on the untreated side (Fig. 9). The microscopic appearances of the marrow and cortex were identical bilaterally. Fatty marrow continued uninterruptedly from shaft into epiphysis with no residue of degeneration, fibrosis, or evidence of abnormal hematopoiesis.

Particular attention was directed to the joints and their contiguous surfaces. These included the patella, the femoral condyles, the upper tibia and attached fibrocartilage, the lower end of the radius, and the carpal bones. Despite some variation in degree, similar changes were noted in all. These were, in the main, degenerative in character; and their presence contrasted strikingly with the inconsequential findings which had been observed during the previous studies on rats.

Without exception, in the present study, all articular cartilages which had been subjected to irradiation showed microscopic evidence of degenerative changes, which increased in severity in direct proportion to the time intervening between treatment and sacrifice. In only one instance could they be considered more than slight to moderate in extent.

One relatively constant observation was the thinness of the treated articular cartilages. In three-fourths of the comparisons, made by actual measurement, the irradiated articular cartilage was only one-half to three-fourths of the thickness of the control joint from the opposite limb. This finding was sufficiently frequent to exclude the possibility of variation in the sectioning angle as a cause, and in no instance was the control cartilage found to be thinner (Figs. 6-A and 6-B). In view of the fact that the treated joint was smaller and the treated bone was shorter than the normal one, it would be surprising if the treated articular cartilage were as thick as that of the control joint. It is probable that the apparent narrowing of the articular cartilage was entirely in keeping with the size of the joint itself.

There was slight variation in the hyaline matrix, and pallor of staining. That the texture of the cartilage was poor was attested by the fraying of the surface, noted in some of the sections. This was not believed to have occurred during life, but was nonetheless considered of some significance. In a few instances (five joints), superficial erosion was present. Cleft formation was rarely seen. In one joint (the radiocarpal joint in Dog No. 7) there was complete, obviously pathological denudation of all cartilage, with exposure of the underlying bone. This was so different from the appearance of any of the other joints that it was considered to be due to undetected trauma. In all other instances the surfaces of the joint cartilage were smooth and adequate for normal function.

The abnormalities of the joint cartilage were minor in degree, and of little functional import. They were recognized only by microscopic study. The cartilage cells in all treated cartilages, however, were abnormal in one respect or another. The changes consisted in loss of polarity and consequent disarrangement of the normal longitudinal

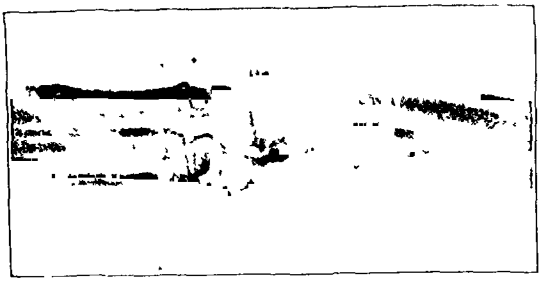
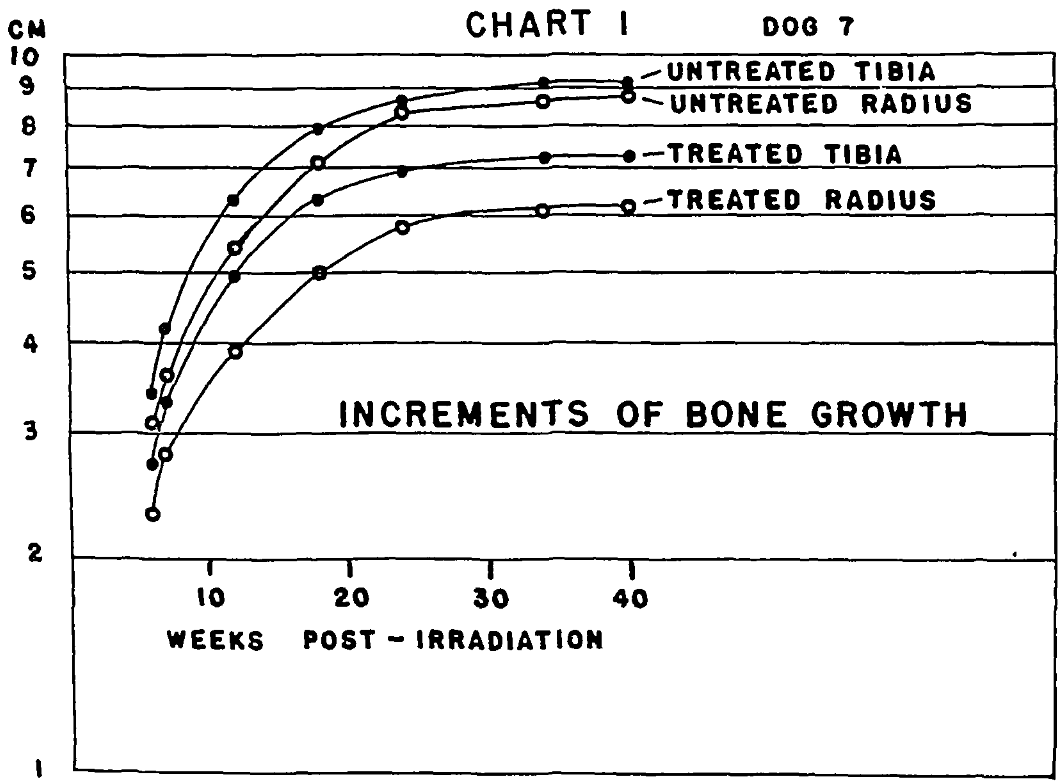


FIG. 2-C

FIG. 3

Fig. 2-C: Roentgenogram of same wrist as in Fig. 2-A, two years after treatment. The contour of the ulna is normal.

Fig. 3: Roentgenogram of Dog No. 2 demonstrates bony resorption in the ulnar metaphysis, twelve weeks after treatment.



Growth retardation was noted in all of the bones treated (Figs. 2-A and 2-B), but the amount and the percentage of retardation varied considerably even within a given dosage group (Tables II, III, and IV). Over-all trends weie apparent. When the percentages of retardation of growth of the long bones in each group were averaged, it became evident that 800 r produced less retardation of growth than 1,000 r (Table V). There was, however, little difference between the effect of 1,000 r and 1,200 r on the radius and ulna.

The range of impedance was wide, but there was close correlation between the mean and the average. In the tibia, the mean impedance was 20 per cent. and the average was 19.3 per cent. In the radius, the mean was 31 per cent. and the average was 32.6 per cent. In the ulna, the mean was 31 per cent. and the average was 31 per cent. The longitudinal growth of the tibiae and radii of Dog No. 7 is plotted on Chart I. The rate of growth was slowest in the treated radius.

The amount of growth contributed by both epiphyses of each tibia and each radius was computed by measurement from the metallic markers which had been placed in the mid-shaft of each long bone (Table VI). In the untreated tibia, longitudinal growth was nearly equal from the proximal and distal epiphyses. In the untreated radius, however,

Fig. 8-A

Fig. 8-B

Fig. 8-A: The patellar cement line in the untreated hind limb of Dog No. 7 (aged two years). Cartilage is similar in appearance to that shown in Fig. 6-A. The sharp, relatively smooth line of division between cartilage and subjacent bone is well shown (× 225).

Fig. 8-B: The cement line in the contralateral treated patella (1,200 r) of Dog No. 7. Scalloping is demonstrated, and the degenerative changes in the articular cartilage are readily appreciated (× 225).

TABLE VIII

AVERAGE RETARDATION OF GROWTH FROM THE TREATED EPIPHYSIS

Group	Amount of Irradiation	Tibia (*Per Cent.*)	Radius (*Per Cent.*)
A	800 r	44	53
B	1,000 r	54	65
C	1,200 r	68	74

two-thirds of the growth resulted from the distal epiphysis and only one-third from the proximal epiphysis. It would be rational to expect, therefore, that the inhibiting effect on growth would be proportionately greater in a radius treated over the distal epiphysis than in a tibia treated over either epiphysis. This is shown to be true by the results listed in Table V. The effect of irradiation on growth of the treated epiphyses is shown in Table VII. The average retardation in the proximal epiphysis of the tibia is 44 per cent. with 800 r, 54 per cent. with 1,000 r, and 68 per cent. with 1,200 r. The distal portion of the radius was retarded 53 per cent. with 800 r, 65 per cent. with 1,000 r, and 74 per cent. with 1,200 r (Table VIII).

One unexpected and interesting observation was that the treated bone was not so short as might have been predicted on the basis of the known amount of retardation of growth of the treated epiphysis. This was caused by the increased rate of growth in the untreated epiphysis of the treated bone (Table IX). In twenty of the twenty-two pairs of limbs, the growth from the untreated epiphyses in the treated limbs exceeded that resulting from their counterparts in the untreated limbs (Charts II and III).

There was a decrease of about 20 per cent. in the diameters of the treated joints, as

TABLE IX

EFFECT OF IRRADIATION ON THE UNTREATED EPIPHYSIS OF A TREATED BONE

No. of Dog	Growth of Distal Portion of Tibia		Growth of Proximal Portion of Radius	
	Untreated (*Millimeters*)	Treated (*Millimeters*)	Untreated (*Millimeters*)	Treated (*Millimeters*)
5	28	34	19	20
6	30	35	22	24
11	28	34	18	19
12	17	19	12	12
3	25	31	16	20
4	33	42	22	28
9	30	37	20	16
10	30	34	17	20
1	26	31		*
2	25	27	18	19
7	26	32	19	22
Averages	27 (15.6%)	32	18 (10%)	20

* In this dog the proximal radial epiphysis was treated. The distal radial epiphysis on the treated side showed increased growth of 11 per cent.

NOTE: Dog No. 8 is not included in this table, as the animal was sacrificed before growth had been completed.

columnar structure (Figs. 7-A and 7-B). There was swelling of lacunae, with or without concomitant abnormalities of the enclosed chondrocytes. The latter varied from cells with normal structure to those with either pyknosis or cytolysis. Frequently, reduplication caused the development of cluster-like aggregations. Changes of this nature were more pronounced in the deep portions of the cartilage, in the vicinity of the subchondral bone; and in two instances small crevice-like cysts were found at the chondro-osseous juncture. In general, there was diminished cellularity, becoming more pronounced as the surface was approached.

Normally in the cement zone, the area in which the articular cartilage and subjacent bone are joined, there is deep basophilia of both bone and cartilage for a short distance; and the line of division is abrupt, sharp, and relatively straight (Fig. 8-A). In treated joints there was considerable variation in the depth of basophilia, and the cement line was irregular and quite strikingly scalloped in appearance (Fig. 8-B). The scalloping was present to a significant degree in almost all treated bones, and probably represented evidence of some change in matrix consistency or mineralization.

Except for this, the subchondral structure was essentially normal. In the single joint in which denudation occurred (radiocarpal joint of Dog No. 7), there was true eburnation, but no other evidence of sclerosis or thickening (Fig. 10). In one case a minute osteophyte had formed at the margin, near the point of capsular insertion. Occasionally a small cluster of trapped chondrocytes was found in the plate, but this also occurred on occasion in the controls. Epiphyseal marrow substance was fatty, and the cancellous structure was normal.

Portions of synovial membrane and capsule were examined in all joints. The capsule was perfectly normal in all except the single instance noted (Dog No. 7). Here there was oedema and a rather marked round-cell infiltration. The synovial membrane was, as a rule, essentially normal. A few minor lesions were found, but these obviously were not primary in nature. In two instances a minute tongue of synovial membrane was affixed to the marginal cartilage in a "creeping" fashion, but no erosive qualities were manifest. In one section, small fibrinoid deposits appeared in several otherwise normal synovial fronds, and in three, fibrinoid flakes were lying free in the cul-de-sac. In one joint there was a tiny loose body, cartilaginous in nature, free in the joint space. Occasionally epithelial-like palisading of the superficial synovial layer was seen,—a feature which could not be considered abnormal, since it occurred also in the untreated joints. One synovial section showed a marked papillary structure without associated inflammation. Two other joints contained a scant sprinkling of lymphocytes and plasma cells.

Sections of skin overlying the epiphyses were also subjected to scrutiny. As noted in the gross examination, the hair shafts appeared coarser; and, in some, depigmentation was noted as well. Nevertheless, histologically, no striking abnormality was evident in any section. Keratosis was normal in amount, and there was no follicular plugging. The corium and subcutaneous tissue showed no fibrosis, elastosis, inflammation, or evidence of vascular injury. The subcutaneous fat and muscle were all normal in appearance.

In summary, the following histological observations were considered significant:

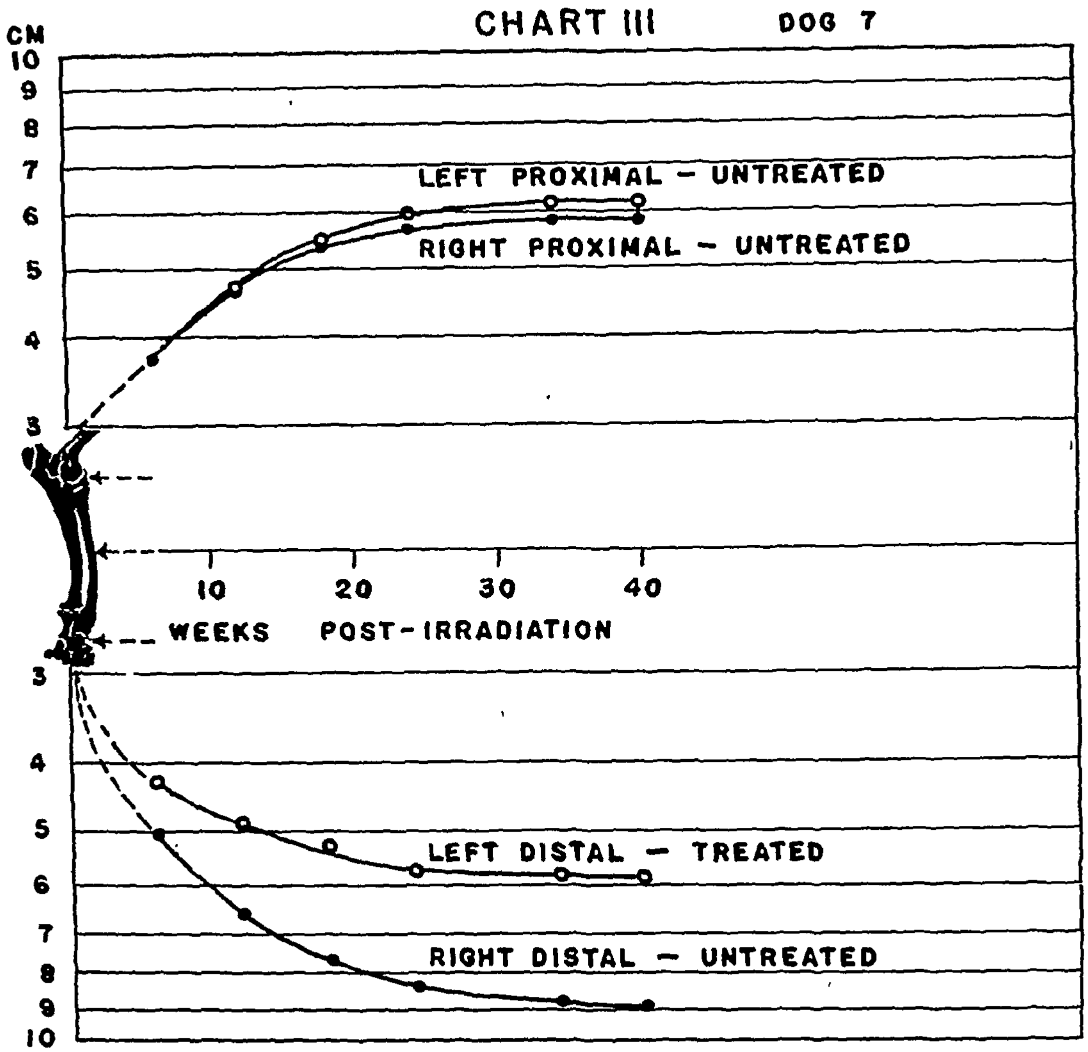
1. The cartilage cells of the epiphyseal plates were profoundly affected by irradiation, and the growth process was interrupted.

2. Following epiphyseal fusion and resorption, no stigma of the previous damage remained.

3. Neither cortical nor cancellous bone nor included marrow showed residual evidence of abnormality.

4. All articular cartilage exposed to irradiation showed, on microscopic examination, evidence of mild degenerative change, save one which showed marked changes, probably due to other causes.

5. There was no evidence of significant abnormality in the synovial membrane, joint capsule, skin, or periarticular soft tissues.



GROWTH OF RADIAL EPIPHYSES (CM)

more shortening than the tibia, treated over the proximal epiphysis. This was probably due to the fact that the distal epiphysis of the foreleg normally contributes two-thirds of the growth increment, whereas the proximal tibial epiphysis normally contributes only one-half.

4. The epiphysis at the untreated end of a treated bone contributes more to the length of the shaft than the corresponding epiphysis in the untreated side. No satisfactory explanation of this stimulation of growth is apparent.

HISTOLOGICAL OBSERVATIONS

Since only one dog in each of the three groups was sacrificed prior to epiphyseal union, only three animals could be studied histologically for the effects of irradiation upon growing epiphyseal cartilage. In these three animals, the treated epiphyses showed severe changes, similar to those described previously in the rat[1, 3, 4]. The treated epiphyseal cartilage showed evidence of very severe damage, and the growth process was practically at a standstill (Figs. 4 and 5). The matrix was palely stained, mottled, and of irregular thickness. Primitive chondrocytes were diminished in number, separated widely, and frequently gathered into clusters without polarity. The columnar arrangement persisted, but in very abnormal fashion. The columns, although arranged in longitudinal fashion, showed deviation in course, and were often grouped together with sparsely cellu-

pending further studies. The bowing of the forelegs which occurred in eight dogs was not sufficiently constant or severe to be considered as a factor in the development of the degenerative joint process.

In the dog, the proportion of growth arising from a given epiphysis was constant. In the tibia, roentgenotherapy of either epiphysis would be expected to produce approximately equal results, as normal growth from the distal and proximal epiphyses is essentially equal. The distal radial epiphysis was found to contribute two-thirds of the longitudinal growth of this bone, and the proximal epiphysis only one-third. Hence artificial inhibition of growth of the proximal epiphysis might be expected to cause only one-half the retardation which would result from arrest of the distal epiphysis.

After irradiation, limited growth continued from the treated epiphysis. In general, it appeared that, with a given dose of irradiation, the degree of retardation was relatively constant. A dosage of 800 r did not produce as much retardation in growth as did dosages of 1,000 r and 1,200 r. Spangler observed that 672 r and 1,992 r, respectively, in divided doses, were not adequate to cause complete arrest of growth in two human cases, and that 2,656 r and 4,300 r, respectively, were sufficient to do so in two other cases. It is believed that complete arrest is not required. Estimation of the amount of shortening desired, knowledge of the proportionate growth index of the various epiphyses, and due regard for the integrity of extra-osseous tissues are factors requiring primary consideration. It is also necessary to take into consideration the data recorded in Table VIII, showing that stimulation of the untreated epiphysis of the irradiated bone usually occurs. Several explanations are possible: The overgrowth might be innately compensatory in character; the minor trauma resulting from limping, due to shortening of the limb, might have acted as a stimulus; or the destructive process in the treated epiphysis might have increased [c]irculation to the bone. This introduces another variable, although possibly predictable, [f]actor to the estimation of anticipated end results.

SUMMARY AND CONCLUSIONS

1. Roentgen dosages of from 800 to 1,200 r were directed over selected joints of six-week-old dogs. The treated area included the joint, epiphysis, and adjacent metaphysis.

2. The epiphyseal cartilage was profoundly affected, and retardation of growth occurred.

3. The articular cartilage of the treated joints showed frank microscopic evidence of degenerative changes, and was not so thick as in the controls. These changes were not sufficient to interfere with joint function during the period of the experiment, and were not apparent on gross examination.

4. There was no evidence of significant abnormality in the adjacent cortical or cancellous bone, synovial membrane, joint capsule, skin, or pariarticular soft tissues.

5. Mild bowing of the treated fore limb occurred in eight of twelve animals. No such deformity occurred in the hind limbs.

6. Although shortening of the treated bone occurred in each instance, there was evidence of stimulation of growth at the untreated epiphysis of the treated long bone. The cause of this stimulating effect is not apparent.

7. The clinical use of roentgen irradiation of growing epiphyses to control longitudinal growth inequalities in children must be considered as experimental, and fraught with some potential dangers. Whether the danger is greater than is incurred in surgical procedures, such as lengthening or shortening of the lower extremity and epiphyseodesis, must await further investigations.

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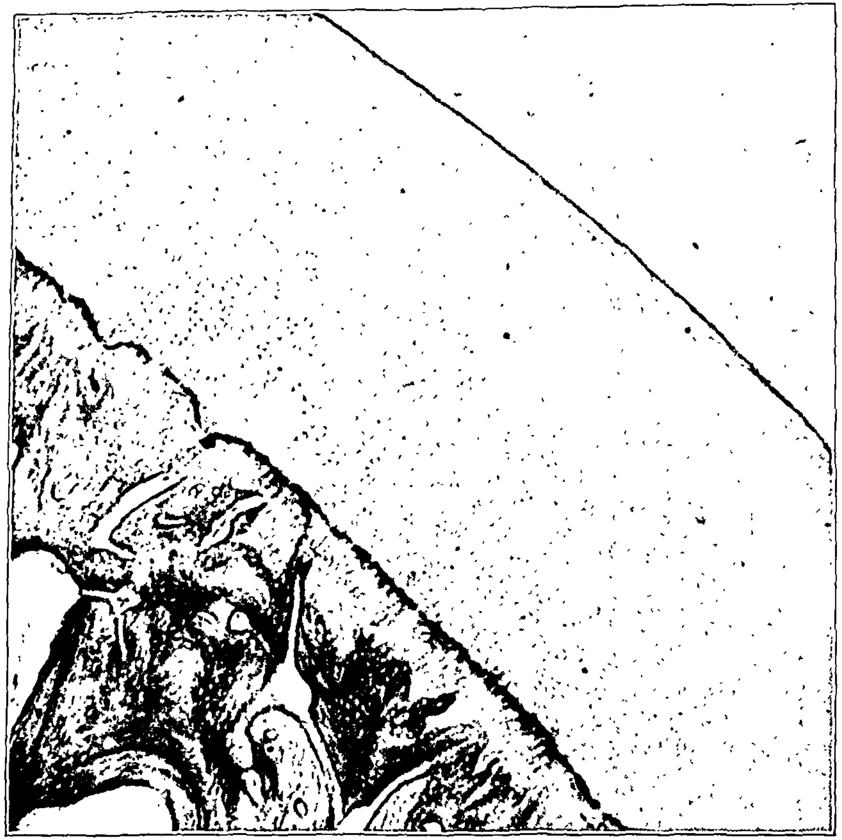

FIG. 6-A

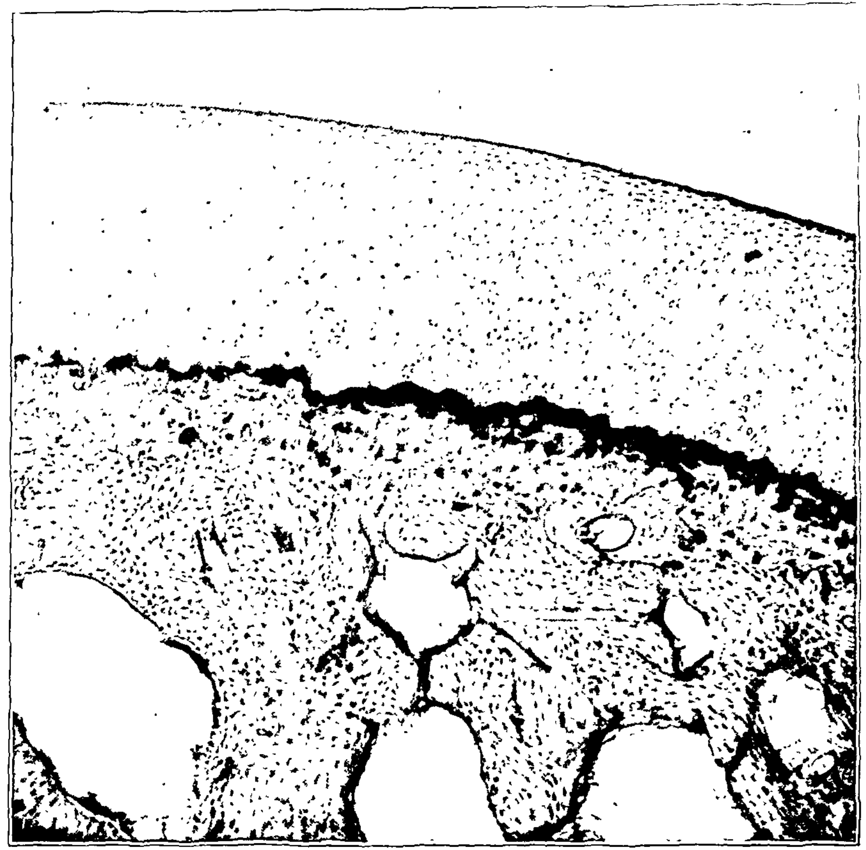

FIG. 6-B

Fig. 6-A: Section of articular surface of the untreated patella in Dog No. 3 (aged one and one-half years). There is a relatively smooth "cement line" between cartilage and underlying bone. The articular surface is sharp, the columns of chondrocytes regular, and the matrix staining character normal. The normal thickness of the cartilage is apparent (× 90).

Fig. 6-B: Articular cartilage of treated patella from Dog No. 3 (1,000 r). The surface remains smooth and the cartilage is thinned, chondrocyte columns are irregular, and the cement line is "scalloped" (× 90).

FUSION OF THE HIP IN CHILDREN

The Chandler Method*

BY CHARLES N. PEASE, M.D., CHICAGO, ILLINOIS

From the Children's Memorial Hospital, Chicago

The approach to the problem of tuberculosis of the hip joint should be directed to the one purpose of eradicating the disease as rapidly as possible with a minimum of risk to the patient. This purpose may be accomplished by the use of the combined intra-articular and extra-articular fusion of the hip joint described by Chandler.

Operations designed to transfer femoral weight-bearing from the hip joint to other regions of the pelvis or to immobilize the hip joint by extra-articular means are not entirely desirable. These methods circumvent the pathological process, which becomes a potential source for metastatic spread. Eikenbary and Lecocq demonstrated an active tuberculous process in the hip joint, despite an excellent extra-articular fusion. The area lying between the superior portion of the femoral neck and the graft, which extended from the trochanter to the ilium, contained tuberculous granulation tissue. A similar observation was made while the author was reviewing one of the cases presented.

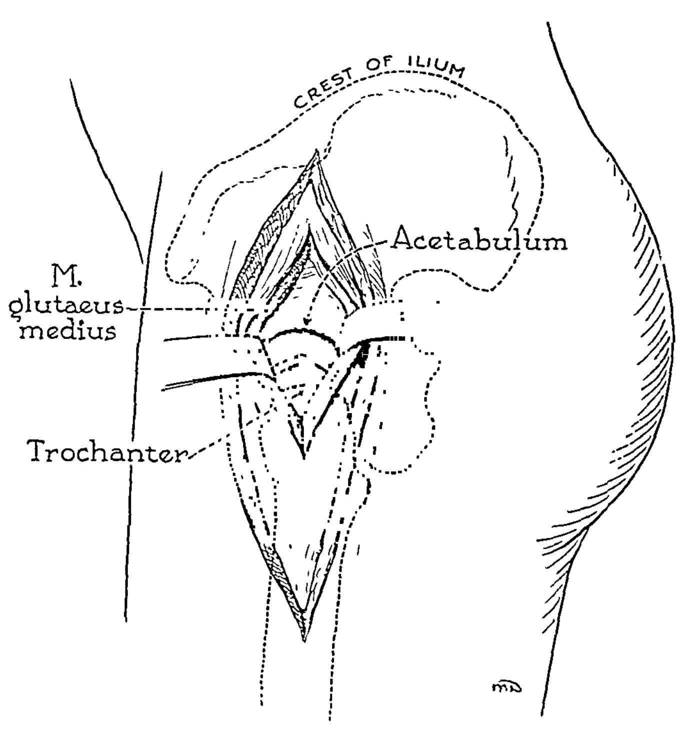

Fig. 1

Lateral incision extending from crest of ilium to five inches below the greater trochanter.

What the Chandler fusion strives to accomplish is not only elimination of motion at the hip joint, but also obliteration, as much as possible, of the areas of bone destruction with the associated soft-tissue involvement. It is a simple procedure; it is one that can be done rapidly; and it is not attended by great danger.

By this operation, an attempt is made to replace the local area of disease by a coalescence of transplanted bone which, in the healing process and together with the surrounding fibrous-tissue formation, obliterates the pathological process. The removal of as much of the necrotic and tuberculous granulation tissue as possible and the substitution of healthy bone produce a favorable site for new-bone formation and connective-tissue growth. The use of the trochanter and a portion of the shaft of the femur, together with bone chips, to produce fusion will be described in detail later. These materials form the foundation from which young connective-tissue cells infiltrate and spread, laying the network for new-bone formation which will cement the affected area. Surrounding the new bone, the fibrous-tissue formation, stimulated by the surgery, will simultaneously invade what remains of the tuberculous granulations and will ultimately replace the latter, thus reversing the process of the disease.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1947.

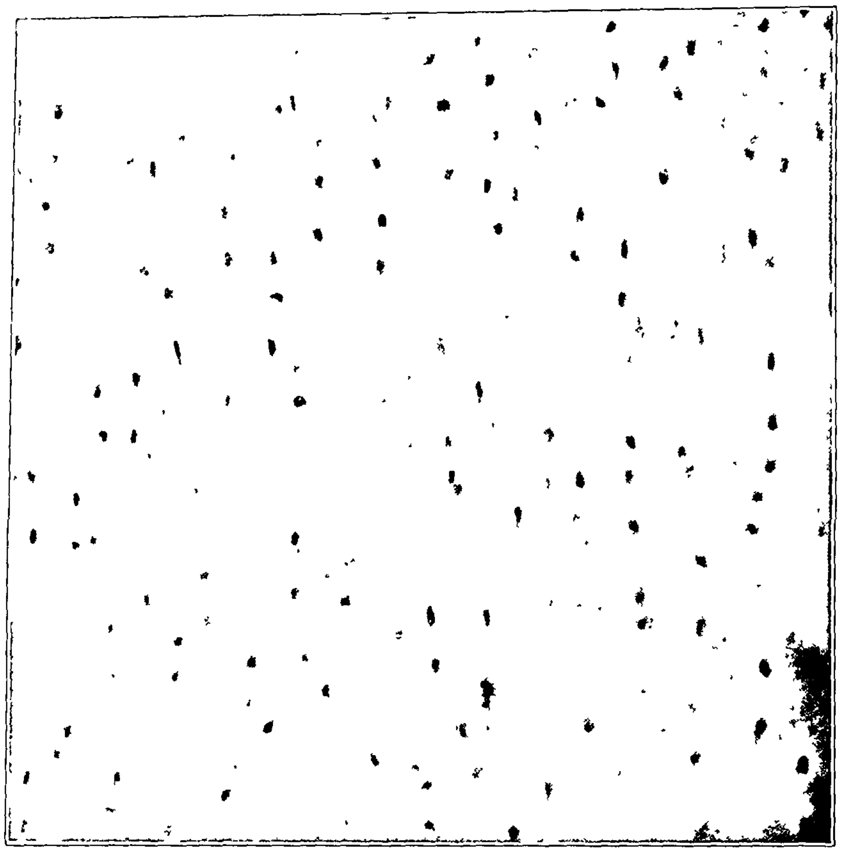

FIG. 7-A

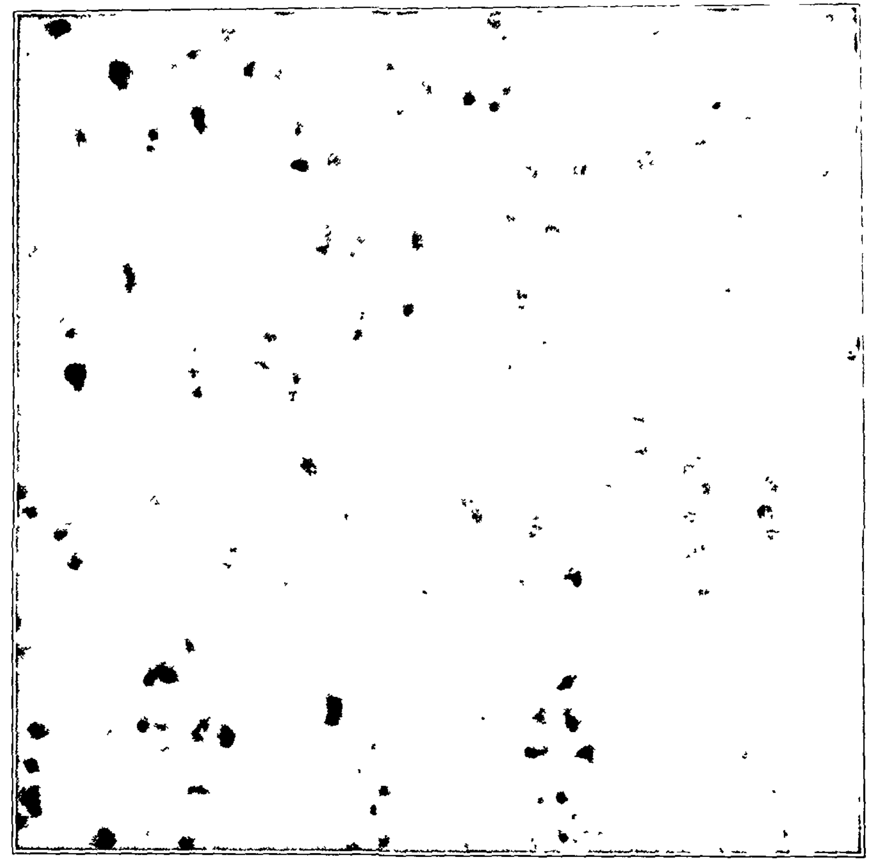

FIG. 7-B

Fig. 7-A: Articular cartilage of untreated patella from Dog No. 4 (aged one year), showing regularity of cartilage-cell arrangement and staining quality. Chondrocytes are small, and their nuclei are single and relatively uniform in size (× 225).

Fig. 7-B: Treated patellar cartilage from Dog No. 4 (1,000 r). Cartilage cells are irregular in size and distribution. Many contain two or more nuclei with varied staining quality, and there are frequently cluster-like aggregations. The staining character of the cartilage matrix is also obviously abnormal (× 225).

Fig. 5-A
A. S., male, aged nine. Tuberculosis of right hip.

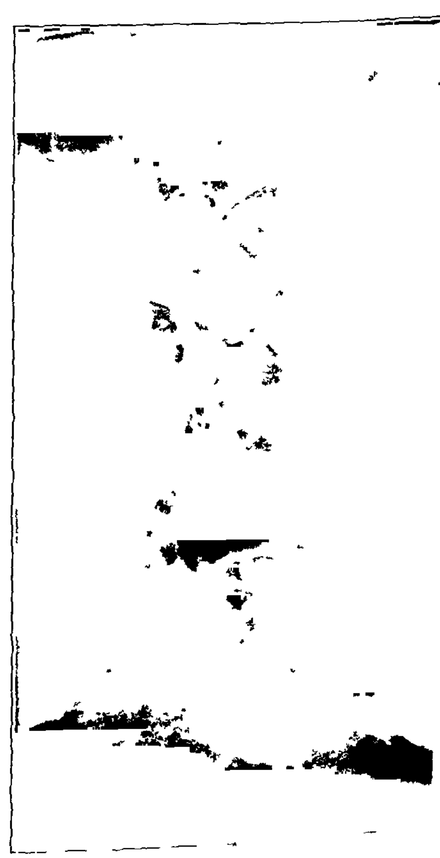

Fig. 5-B
After fusion of right hip

Fig. 5-C
Two months after operation.

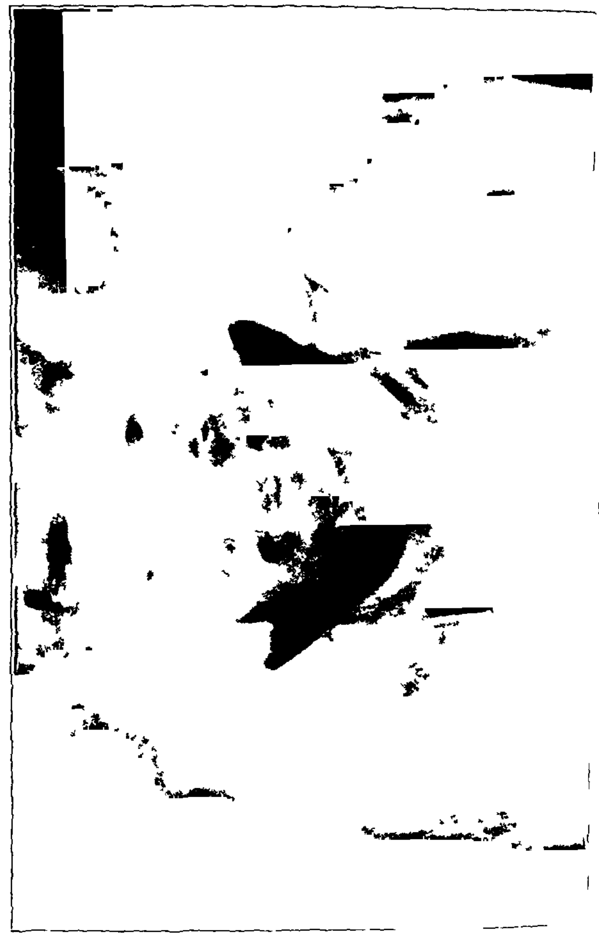

Fig. 5-D
Six years after operation.

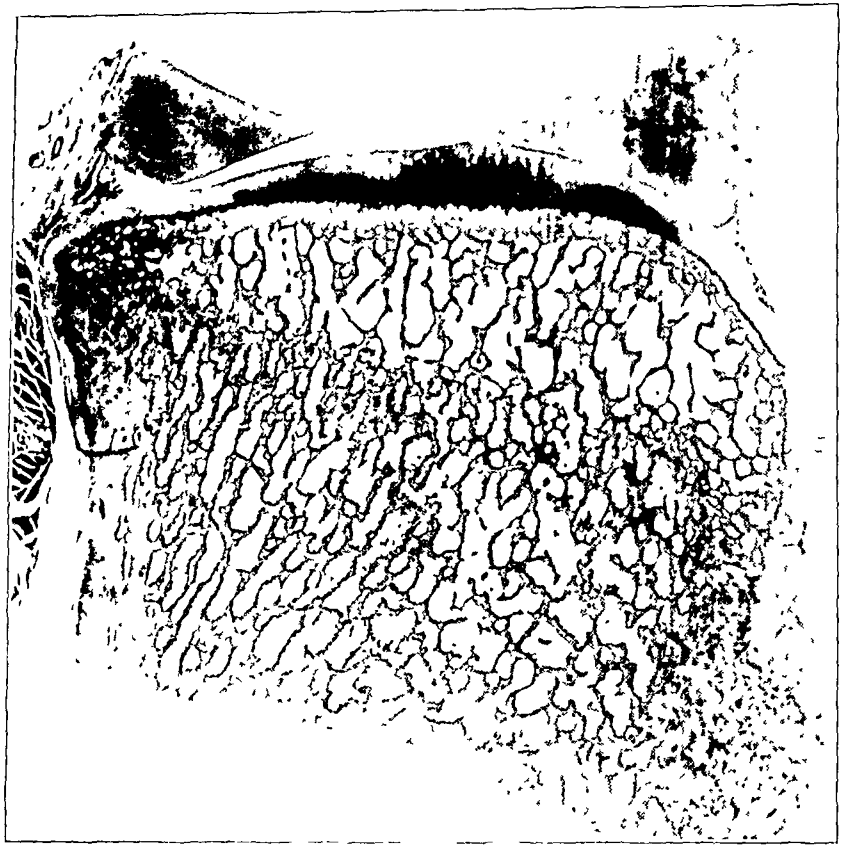

Fig. 9

Fig. 10

Fig. 9: Tibia from the treated limb of Dog No 4 (aged one year). Normal contours persist. The line of epiphyseal fusion is shown by the horizontal dense zone of cancellous bone. This is identical in appearance to the contralateral untreated limb (× 9).

Fig. 10: Articular surface of lower end of radius in Dog No 7 (aged two years), treated with 1,200 r. There is denudation of cartilage and eburnation of the exposed bone. Trabeculae are coarse, and the marrow spaces which extend directly to the cartilage-free surface are fibrous in content (× 225).

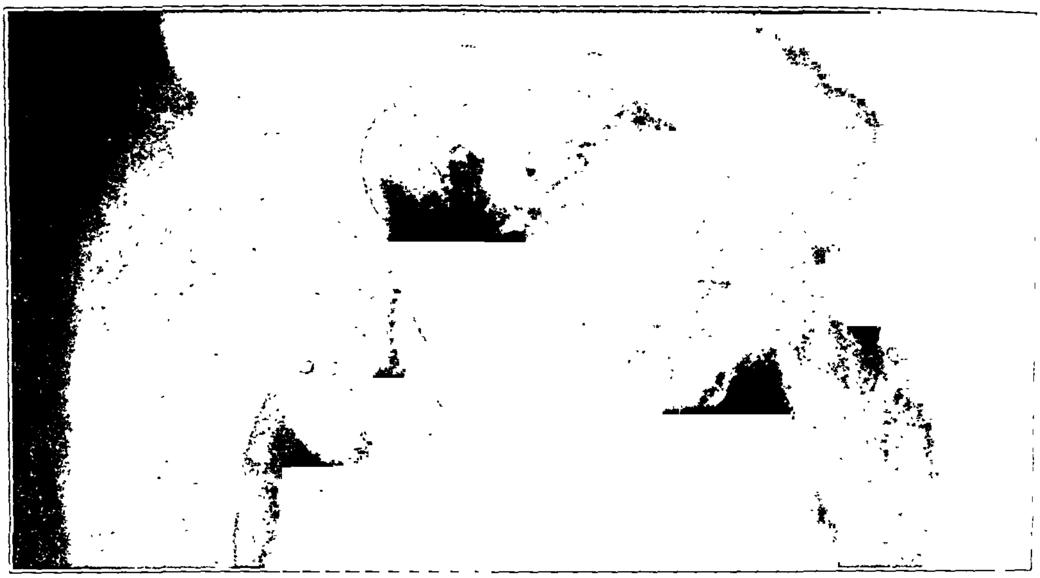

FIG. 7-A
E. R., female, aged eleven. Tuberculosis of left hip.

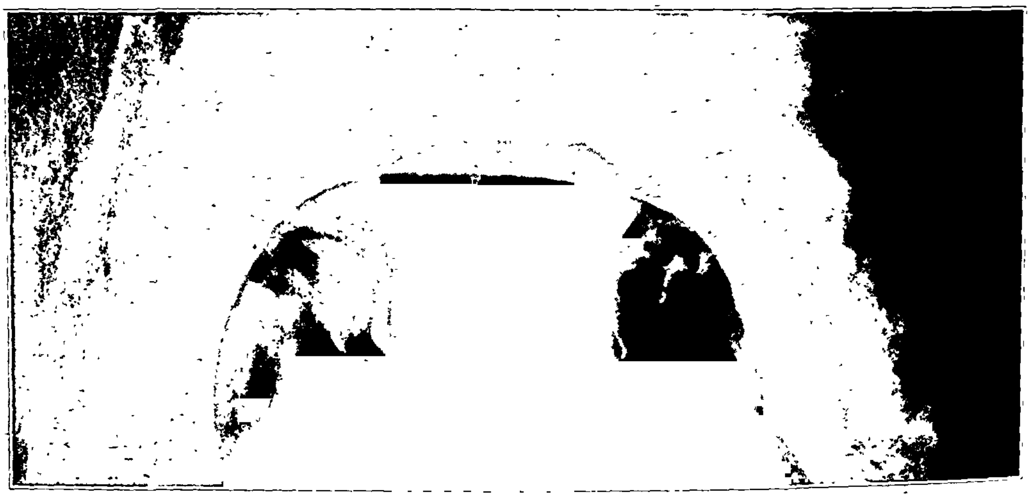

FIG. 7-B
After fusion of left hip.

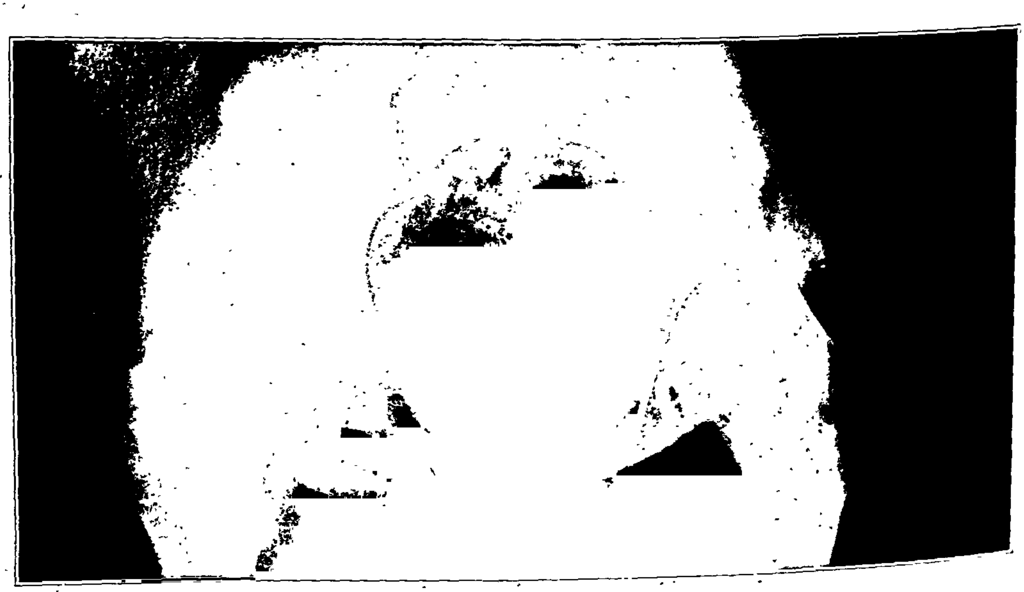

FIG. 7-C
Two years after operation.

DISCUSSION

Particular attention must be directed toward the possible delayed effects of roentgen treatment, if it is to be applied therapeutically to retard growth of the human limb. In the present study, moderate dosages were utilized, and produced the anticipated inhibiting effect upon the epiphyseal cartilage. The morphological changes in this structure, which appeared soon after treatment, were similar to those previously noted in the rat [1, 3, 4]. Late morphological changes were not comparable with the results in the rat, because the epiphyses of the rat do not fuse with the diaphyses. The present study on the dog showed that fusion and resorption of the epiphyseal plate occurred, and that all evidence of intraosseous damage disappeared. Save for diminished length, the treated bone itself differed only in minor respects from its untreated counterpart. The treated joint was somewhat smaller than the untreated one.

Of utmost importance in this study was the determination of the relative roentgen susceptibility of epiphyseal cartilage as compared with articular cartilage. Articular cartilage in the rat had been found in the authors' studies and in those of others to be comparatively resistant to the roentgen ray [1, 3, 5]. Horwitz and Dillman observed the histological changes in four dogs, given from 3,000 to 8,000 r in fractionated doses over joints when one year of age. These dogs were sacrificed at intervals between twelve and sixteen months after treatment, and no abnormalities were noted in articular cartilages, subchondral bone, synovial tissue, joint capsule, or investing soft tissues. Two other dogs, similarly treated, were followed for longer periods, and showed no roentgenographic evidence of joint disease. These authors state, however: "Despite the experience that much larger doses applied to the more vulnerable joints of our dogs were without immediate and, thus far, remote deleterious effects, it is our experience that very heavy roentgen-ray dosage will affect normal human joints adversely."

Engel found that both fibrocartilage and hyaline cartilage were resistant to large amounts of irradiation.

Contrary to expectations based upon the authors' earlier experiments on the rat, the articular cartilage in dogs showed histological evidence of degenerative change. Since no animal was studied earlier than the fourth month after treatment, it is not possible to state that the damage to the epiphyseal and articular cartilages occurred simultaneously. The damage appeared to increase with time, although in only one of the twenty-four joints could it be classified as severe. This one case of pronounced arthritis was assumed to be due to some unknown cause.

The lesion found in all treated articular cartilages (patella, tibia, femur, radius, ulna, and carpal bones) consisted of disarrangement and diminution of chondrocytes, thinning of the cartilage, and a minor degree of change in the texture of the matrix and scalloping of the cement line. With the one exception noted, there were no striking gross joint changes. The articular surfaces were, for the most part, smooth and perfectly adequate for normal function. It is probable that the durability of these cartilages was less than that in the untreated areas, and that deterioration with continued use would be greater. This was demonstrated by the increased degeneration apparent in those animals sacrificed late in the experiment.

Although one is justified in presuming that these degenerative lesions are the result of the irradiation per se, Horwitz and Dillman found no articular changes in the dogs which they treated at one year of age, after the growth process had ceased spontaneously. In these animals, in which maximum leg length had been attained, no shortening should have resulted; and the trauma caused by limping must have been absent. Furthermore, rats receiving similar amounts of irradiation, but with movement and weight-bearing restricted by confinement in small cages, did not show any such degenerative process. Hence it is possible that the deformity (shortening) produced by irradiation was the basis for the articular lesion, and not the irradiation itself. This problem must remain unsettled,

FIG. 8-C
Eleven years after operation.

to twelve years, the average age being seven and seven-tenths years. Patients were not selected on the basis of risk, as demonstrated by the fact that three children also had tuberculosis of the spine, three had tuberculosis of the kidney requiring nephrectomy, two had tuberculosis of the elbow joint, one had tuberculosis of the sacro-iliac joint, and one had tuberculosis of the knee joint.

FIG. 9-A
H. N., male, aged ten. Tuberculosis of left hip.

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DISCUSSION

DR. FREDERIC C. BOST, SAN FRANCISCO, CALIFORNIA: The report of roentgen exposure as a means of arresting epiphyseal growth, presented by Dr. Reidy, arouses considerable interest. Thus far, this work is purely experimental, and it should not be applied to the treatment of inequalities of limb length in children. The experiments reported by these authors show definite complications, such as unequal growth of the epiphyses, failure of growth of the epiphyseal body, and some degenerative changes following irradiation. Such complications might lead to serious disturbances in function, which could not be tolerated by the human joint. The fact that the varying doses of roentgen exposure give rise to varying degrees of epiphyseal arrest is of more than passing interest. After further experimental trial, some means might be found to eliminate the complications noted in this study, so that in the future some clinical application might be found for this method of treatment.

DR. J. WARREN WHITE, GREENVILLE, SOUTH CAROLINA: In Dr. Reidy's remarks, there was a question as to why there was some growth at the free end of the bone, even of bone that had received roentgen treatment. I think we can explain that from the fact that roentgen treatment has produced a generalized hyperaemia of the extremity. That is a clue which we can follow in possibly stimulating growth in the short leg.

I was disappointed in the evidence of the arthritis that was found in the dogs' joints. About six or seven years ago, Dr. Warner and I carried on some unpublished experimental work on radiological retardation; and our feeling was, after we had treated five cases in children, that we were unjustified in continuing, in view of the fact that we were getting skin damage with our animals which were being treated intensively. It is apparent that, until we get a more encouraging report from these investigators, further retardation by roentgen rays should be postponed.

DR. D. B. PHEMISTER, CHICAGO, ILLINOIS: The interesting investigative work presented has emphasized the fact that much remains to be accomplished before growth-arrest procedures for equalization of length in the extremities reach their final stage of perfection. If retardation of bone growth by roentgen rays is to be utilized clinically, it will be for equalization of length of the lower limbs. In the upper extremity, the indication is for equalization of the length of the radius and ulna in cases in which either bone is short as a result of growth arrest at the lower end. This calls for complete arrest of growth at the lower end of the other bone, combined in some cases with resection of a segment of the metaphysis, which can only be accomplished by operation.

TECHNIQUE

Hibbs first used the trochanter in extra-articular fusion of the hip, but Chandler employs it in the combined operation. Although the technique of this operation has been reported previously, a brief description of the method may be repeated at this time. The patient is placed on his side, and the hip to be operated upon is elevated at an angle of 45 degrees. A lateral incision is made, extending from just below the crest of the ilium to the junction of the upper and middle thirds of the thigh. There is no extensive separation of fascial or muscle layers; only enough dissection is done to facilitate suture. The incision is deepened by splitting the fibers of the tensor fasciae latae, and is then carried through the vastus lateralis and the periosteum, and upwards through the glutaeus medius parallel to the muscle fibers, exposing the superior portion of the femoral neck and crossing the hip joint at right angles to the upper acetabular margin (Fig. 1). With a wide osteotome, bone flaps are elevated medially and laterally from the base of the femoral neck downward for three to five inches (Fig. 2), depending upon the age of the patient. The acetabulum and adjacent ilium are exposed by reflecting the joint capsule.

With an osteotome, a graft, consisting of a generous portion of the trochanter and including three to five inches of the shaft of the femur, is made, by means of parallel incisions into the bone, which converge distally. The graft is removed gently and placed in a gauze dressing saturated with Ringer's solution. The femoral neck and head come plainly into view. The articular surfaces of the head of the femur and the acetabulum are removed with a curette or chisel. On some occasions, the hip has been dislocated by slight adduction and external rotation of the shaft of the femur; this facilitates removal of the articular cartilage.

A hinged flap is elevated from the ilium at or slightly above the acetabular margin by inserting an osteotome at the selected site. A recess is made beneath this flap to receive the graft.

Bone chips are taken from the margins of the shaft of the femur where the graft was removed or from the exposed ilium, and are firmly packed into the superior portion of the hip joint (Fig. 3). The trochanteric graft is then turned end for end and driven into the recess in the ilium (Fig. 4). The thigh may be adducted to facilitate the driving of the graft into the ilium. Upon abduction of the femur, the graft is locked into position. The osteoperiosteal flaps, made prior to the removal of the graft, make a closure favorable to osteogenesis.

After closure of the wound, a double spica cast is applied, extending to the toes on the side operated upon and to the knee on the opposite side. After a period of from six weeks to ten weeks, this cast is replaced by a single spica cast, which extends to just above the malleoli.

The limb in plaster should be in complete extension and in sufficient abduction to maintain the locked position of the graft, even if it has to be extreme abduction. This latter position is not considered optimum, but eradication of the disease is the most important requisite and any resulting deformity can be corrected later.

Despite the wide abduction and extension positions of the hip, it has never been necessary to perform an osteotomy to correct these positions. In all instances, however, a decrease in the degree of abduction has occurred during growth, by virtue of the powerful action of the adductor muscles (Figs. 5-B, 5-C, 5-D, 6-C, 6-D, 7-B, and 7-C).

AFTER-CARE

The postoperative care of these children may differ from the conventional type which is being used today. If the child's general condition is satisfactory, no restraint is used to limit activity; instead, it is encouraged. If a child shows a desire to stand or walk while he is in plaster, he is permitted to do so. This is an attempt to return the patient to a more

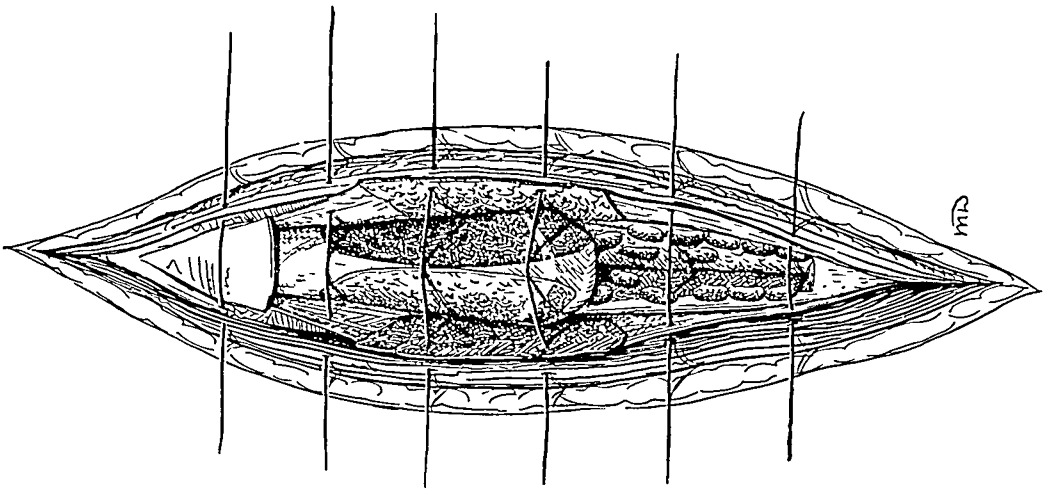

Fig. 4

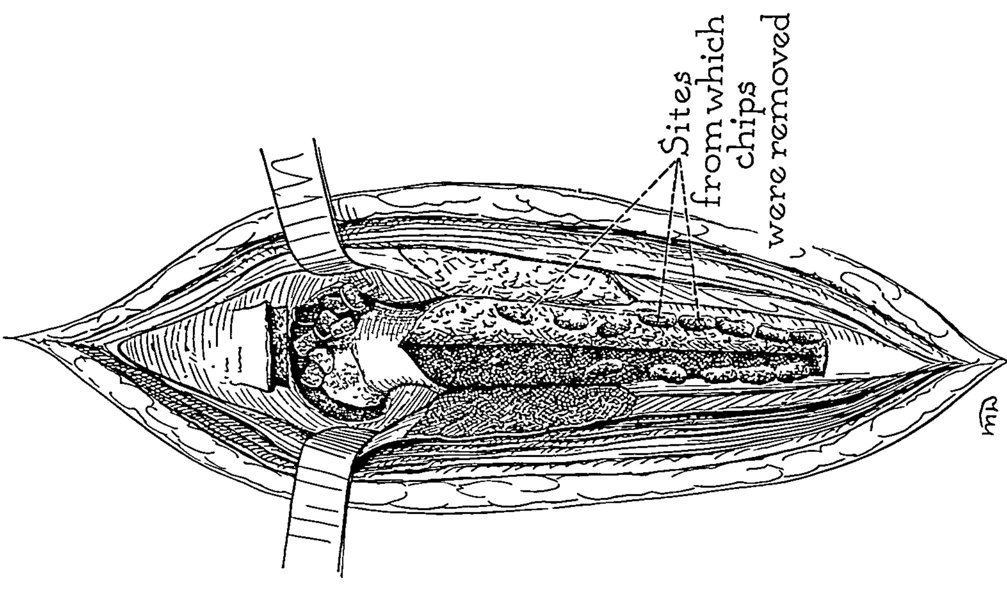

Fig. 3

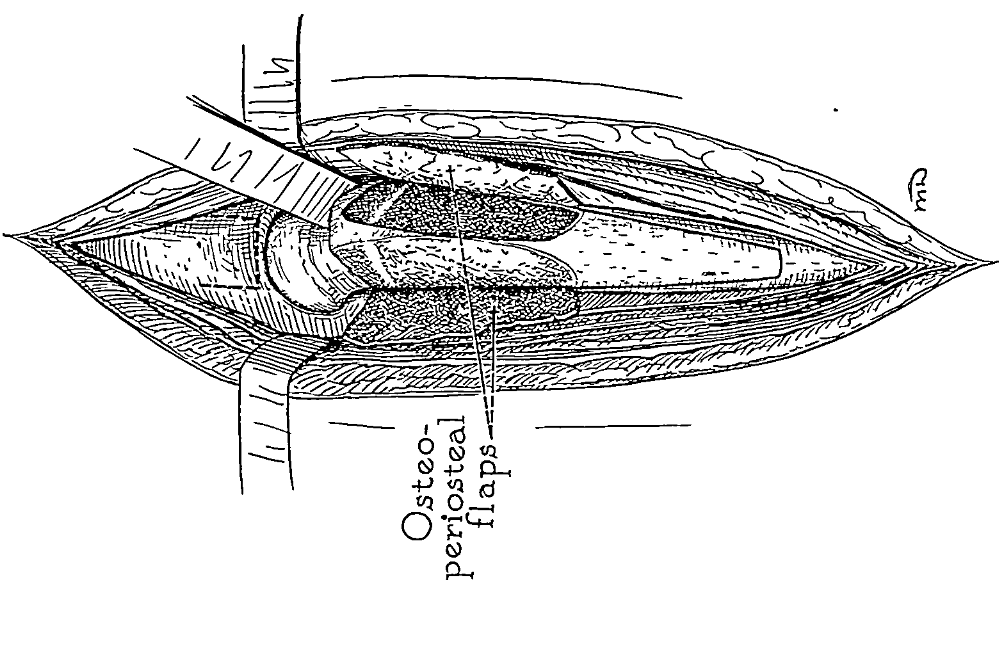

Fig. 2

Fig. 2: Osteoperiosteal flaps are elevated, after which trochanteric graft is removed. Recess in ilium is made at margin of acetabulum.
Fig. 3: Articular cartilage has been removed from head of femur and acetabulum. Joint space has been packed with bone chips taken from femoral shaft or ilium.
Fig. 4: Trochanteric graft has been turned end for end, and has been driven into recess in ilium. Osteoperiosteal flaps are sutured over graft.

Fig. 11-A
L. U., female, aged six. Tuberculosis of right hip.

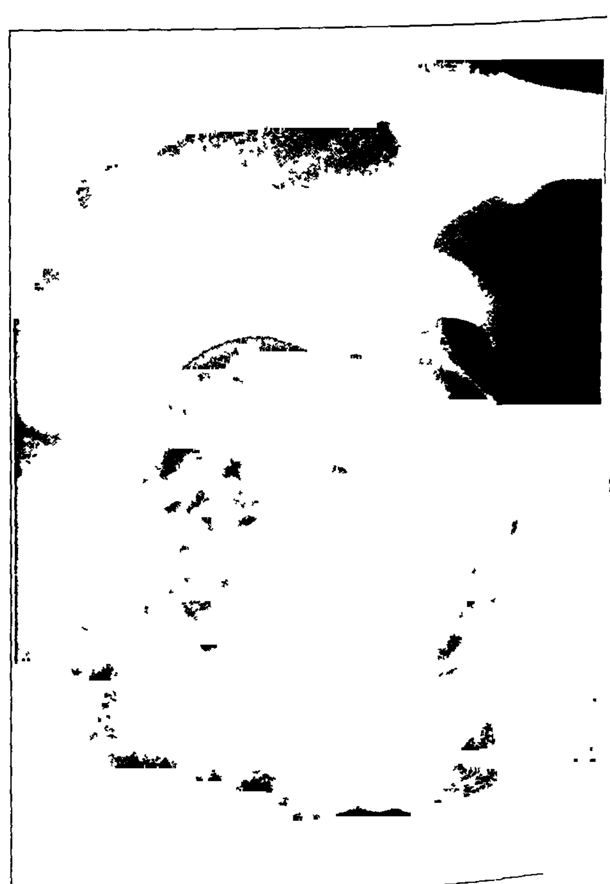

Fig. 11-B
Six years after operation.

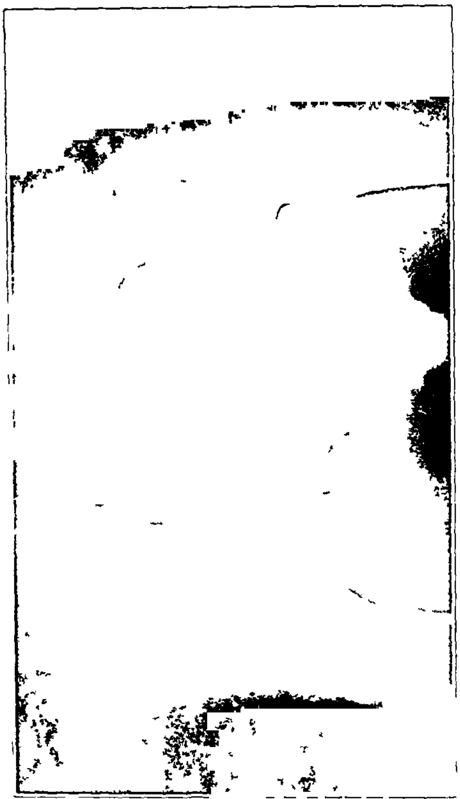

Fig. 12-A
A. H., male, aged six. Tuberculosis of left hip.

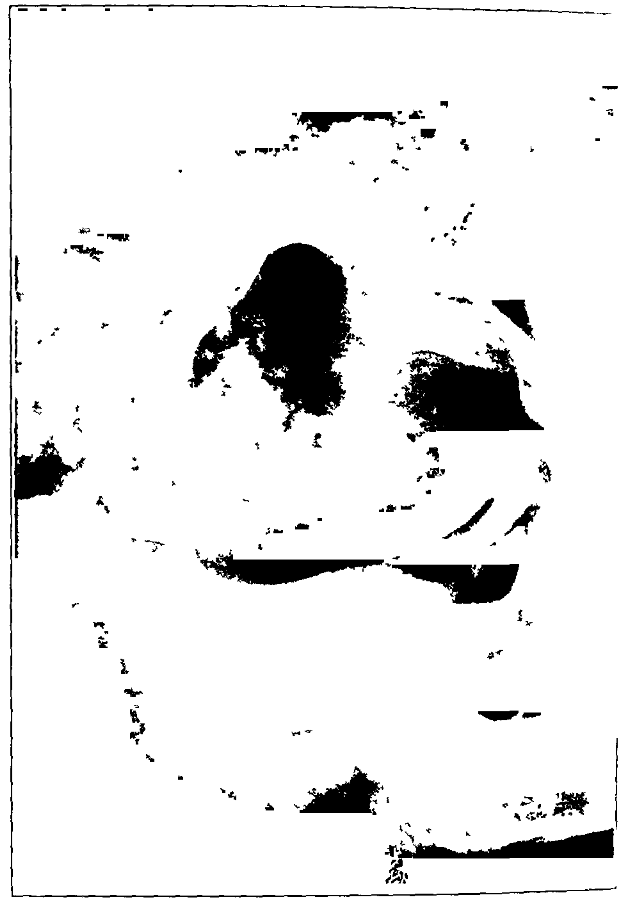

Fig. 12-B
Five years after operation.

FIG. 6-A

D. L., male, aged seven Tuberculosis of left hip Boy failed to return to Clinic.

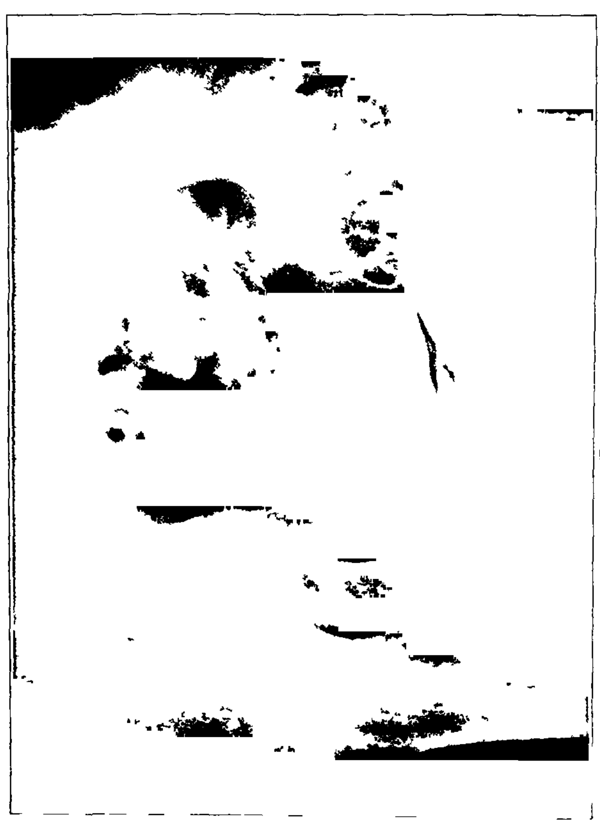

FIG. 6-B

Condition of hip upon return to Clinic after five years.

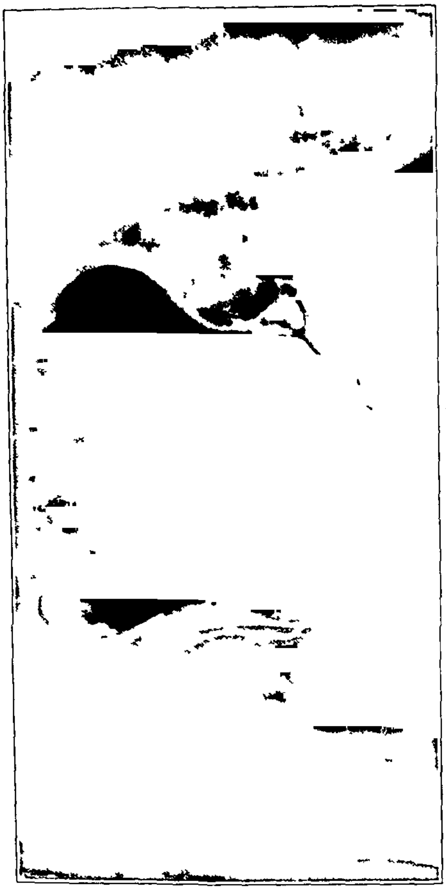

FIG. 6-C

One week later hip fusion was done.

FIG. 6-D

Eleven years after operation.

Fig. 15-A

Fig. 15-B

Fig. 15-A: D. O'D., female, aged four. Tuberculosis of left hip and sacro-iliac joint.
Fig. 15-B: Six years after fusion of right sacro-iliac and left hip joints. Note calcified abscess in right pelvis. This child also had had a tuberculous kidney removed.

This study consisted of a five-year follow-up of twenty-eight children upon whom the Chandler operation had been performed. Twenty-three fusions were done for tuberculosis of the hip, four for quiescent pyogenic infection, and one for congenital dislocation of the hip which had been operated upon with a poor result. Ages varied from fourteen months

FIG. 8-A
A. R., male, aged six. Tuberculosis of right hip.

FIG. 8-B
Appearance of hip after two years. Patient had had cast treatment elsewhere.

Chandler has been doing a preliminary intrapelvic, extraperitoneal section of the obturator nerve on patients requiring hip arthroplasty, in order to overcome postoperative adductor spasm. Such section of the obturator nerve has been performed recently in conjunction with hip fusion in six children. It is hoped that this will eliminate pseudarthrosis and adduction deformity. In addition, this procedure is expected to prevent the flexion deformity of the hip, which occurs simultaneously with adduction. Theoretically, this nerve section should result in adduction, because the iliopsoas does not exert its fullest power with the leg in abduction (Fig. 10). Whether or not obturator-nerve section will result in a more favorable condition for fusion in the six cases in which it has already been performed cannot be stated yet, since sufficient time has not elapsed to observe the final results.

COMMENT

The method described has simplified hip fusion and by its use excellent end results have been obtained. Some surgeons have objected to operating through an area with an active tuberculous process. However, the same objections are not usually raised in the case of active tuberculosis of the knee joint. The study of the cases herein reported does not indicate that there have been any harmful effects; but, on the other hand, it has shown that definite benefit is derived from direct early elimination of an active tuberculous process.

The combined intra-articular and extra-articular fusion stimulates not only new-bone formation for the production of fusion, but also considerable fibrous-tissue formation, which replaces tuberculous granulation tissue and obliterates the infected areas in the same manner as thoracoplasty.

Obturator-nerve section, combined with hip fusion, appears to hold promise of a decrease in the incidence of pseudarthrosis and deformity.

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Pseudarthrosis occurred in three cases. One child was operated upon three times before a satisfactory result was obtained, while three children were operated upon twice.

There were no deaths immediately following surgery, but one child, who also had a tuberculous knee joint and a tuberculous kidney, died from tuberculous meningitis one year following the hip fusion. Two children in whom tuberculosis of the cervicothoracic and cervical spine had developed, one and one-half and two years, respectively, following hip fusion, also died from tuberculous meningitis.

Fig. 9-B
Two years after operation Hip sinus was draining Tuberculous kidney had been removed

Fig. 9-C
Thirteen years after operation.

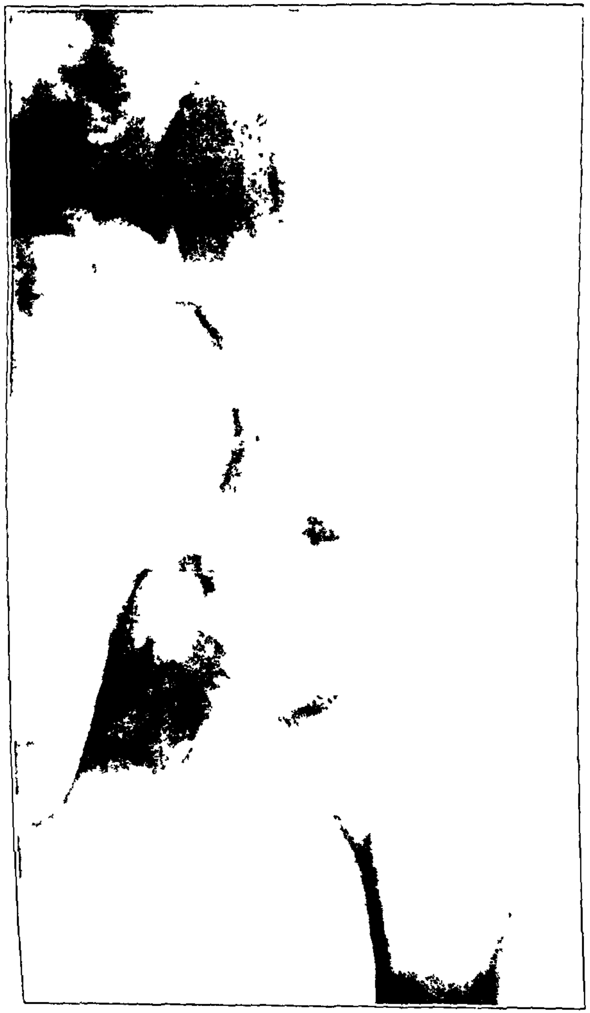

FIG. 1-A

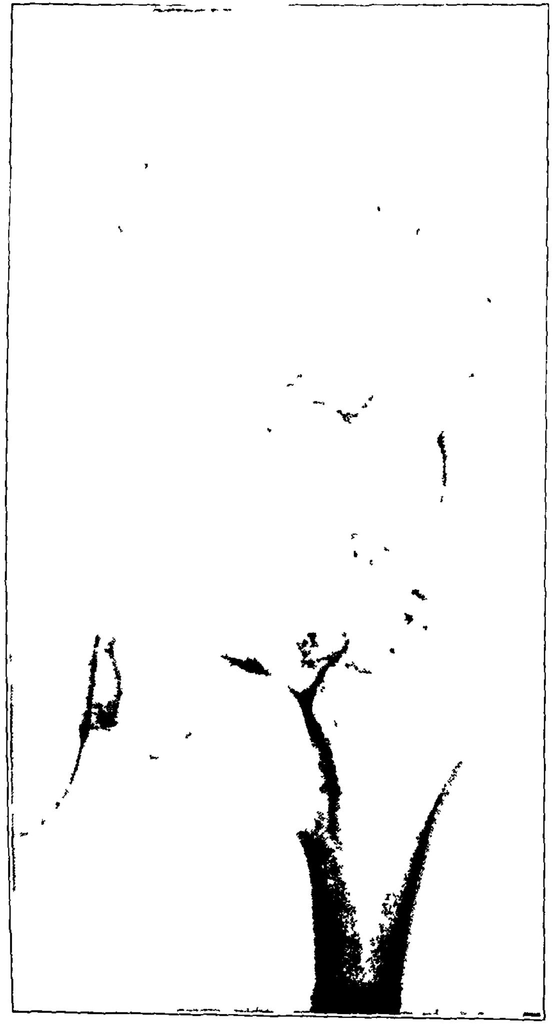

FIG. 1-B

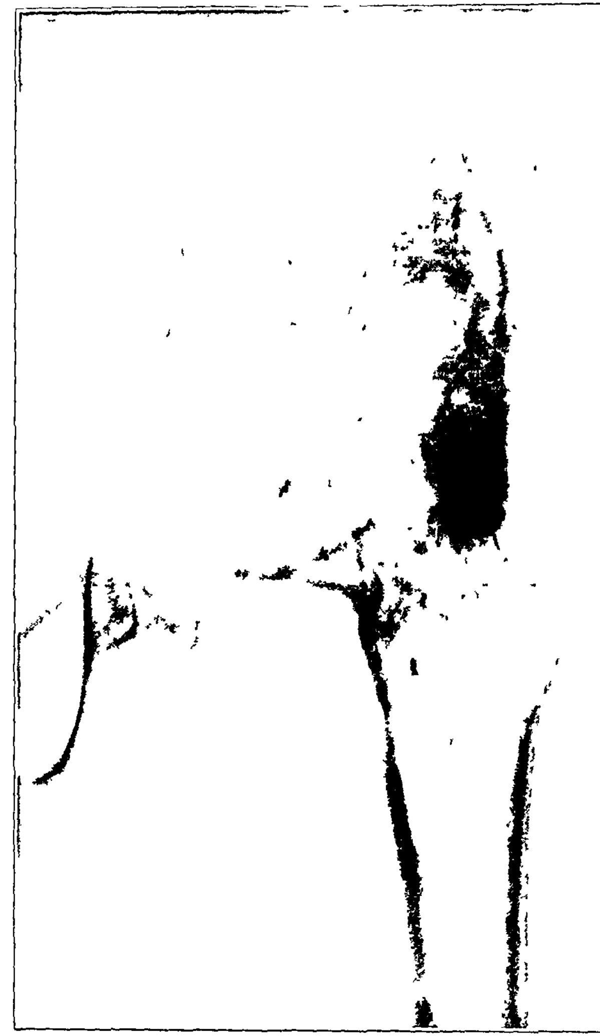

FIG. 1-C

FIG. 1-A: Case D. K., at three years of age. Roentgenogram shows early tuberculosis of the left hip with a primary osseous lesion on the acetabular side of the joint. Symptoms at this time had been present for only a few months.

FIG. 1-B: Three years later. Roentgenogram shows massive destruction of the entire acetabular aspect of the joint with secondary destructive changes in the femoral head and neck. Beginning sclerosis of the bone margin about the superior edge of the destructive lesion is also evident.

FIG. 1-C: Six years later. Appearance of hip, six months after extra-articular arthrodesis with iliac-bone graft.

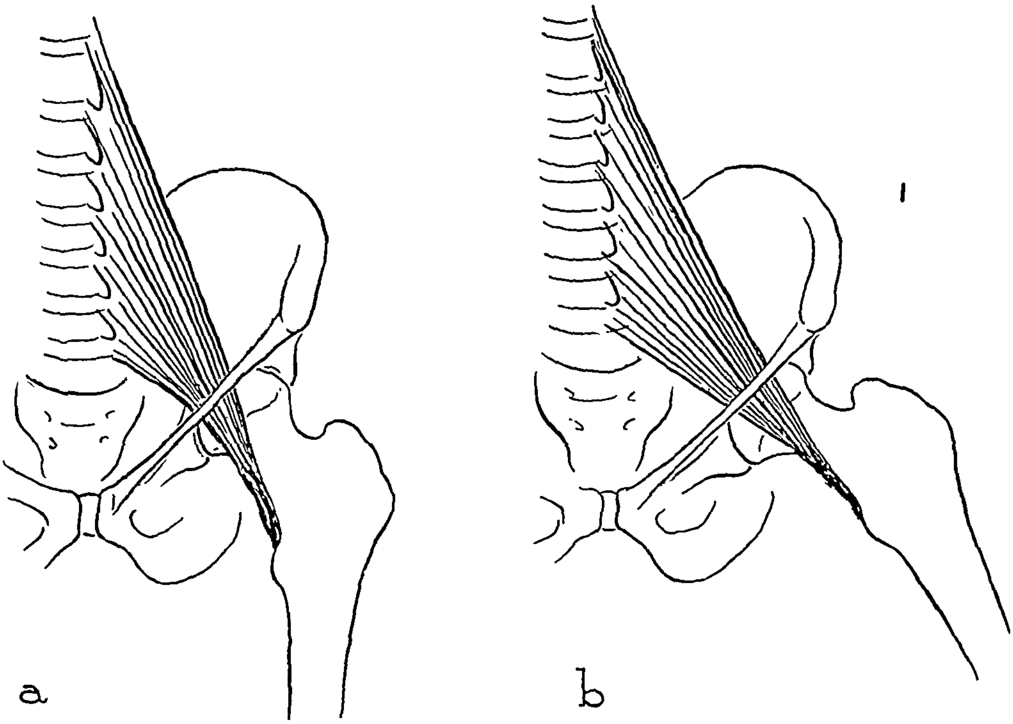

FIG. 10

a: Schematic drawing of iliopsoas muscle in position for its most efficient pull.
b: With limb abducted, iliopsoas does not exert its greatest power. With the elimination of adductor force by obturator-nerve section, there should be less likelihood of flexion as well as of adduction deformity.

normal physical status. With the approach to normal physical activity, conditions are favorable for improvement of all bodily functions, thereby stimulating physical and chemical processes conducive to tissue repair.

The minimum time in plaster was four months; the maximum, twenty-six; the average, eleven months.

Transfusions with whole blood or packed cells are given if the erythrocyte count is below normal. A high-caloric diet and one rich in protein and minerals is desirable. Codliver oil is given daily.

When the chart indicates that no gain in weight has been made, complete rest is ordered. Roentgenograms of the hip are examined for possible active disease, and evidence of metastasis is looked for in other parts of the body.

Routine guinea-pig inoculation with urine from all patients under active treatment should be done every six months, since two of the three patients who had concomitant tuberculous kidneys exhibited no urinary symptoms. It was only after positive guinea-pig findings that pyelograms were made which demonstrated destructive processes on one kidney of each child.

Draining sinuses occurred in four patients postoperatively. Discharge persisted for two, ten, twenty-four, and thirty-two months, respectively. All hips fused solidly in spite of the discharging sinuses.

Adduction and flexion deformity occurred in three cases, which required correction by osteotomy. There are two other patients who are in need of osteotomies, because of adduction and flexion deformity.

OBTURATOR-NERVE SECTION

The power of the adductor muscle was not only a factor in producing postoperative deformity, but was also considered a possible cause for failure of fusion. Elimination of this force should favor a more satisfactory end result in hip fusion.

reasoning is justified from the results, since arthrodesis is more easily obtained in a hip of this type than in that of a younger child or in the presence of a lesion which is still progressing rapidly. Of forty-three hips immobilized for from two to eight years in preparation

Fig. 2-A

Fig. 2-B

Fig. 2-A: Case D. R., aged six years. Roentgenogram shows early tuberculosis of the left hip, with primary osseous lesion in the metaphyseal region of the neck, and partial dislocation of the hip from muscle spasm. The hip joint itself was still uninvolved.

Fig. 2-B: Five years later. Early reduction had been brought about by skin traction, and position was maintained with plaster fixation. Destructive lesion was still localized to the femoral neck and contained a definite sequestrum. Destruction of the hip joint had not occurred.

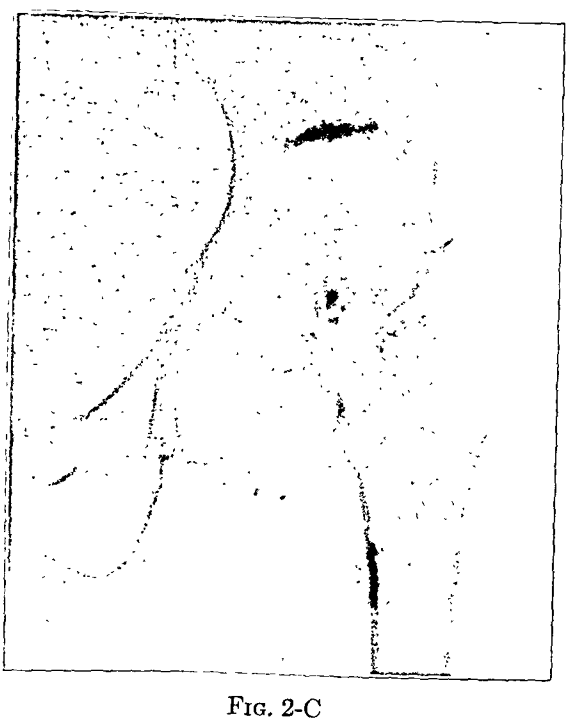

Fig. 2-C

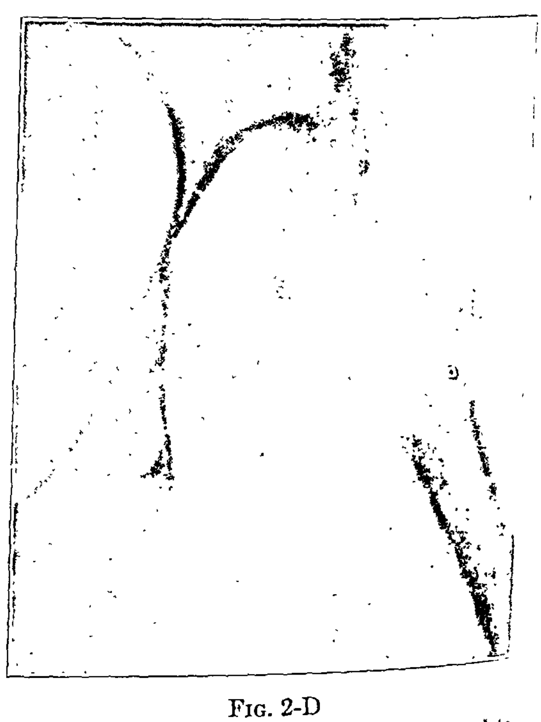

Fig. 2-D

Fig. 2-C: Seven years later. Massive extension of the destructive process had occurred, with complete disintegration of the hip joint. Limiting wall of increased bone density is seen about the periphery of the defect.

Fig. 2-D: Six months after an intra-articular arthrodesis with a massive tibial-bone graft, extending from the ilium into the trochanter. Absorption of the graft at its mid-point, by invasion of the tuberculous tissue, had begun.

Fig. 13-A

V. M., female, aged ten. Tuberculosis of right hip.

Fig. 14-A

W. H., male, aged seven. *Bacteroides funduliformis* infection of right hip.

Fig. 13-B

Two years after operation.

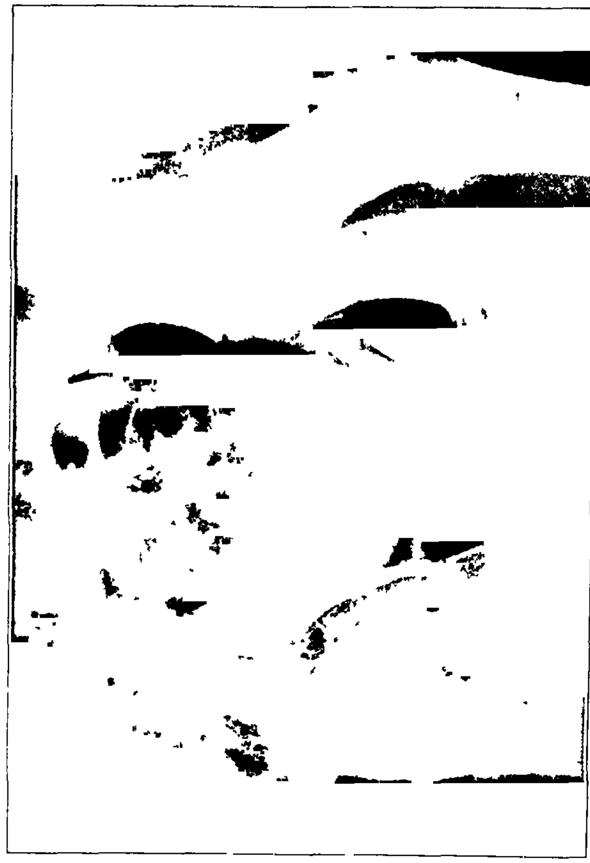

Fig. 14-B

Three years after operation.

TABLE I

RESULTS OF ATTEMPTED ARTHRODESIS OF THE HIP

	Number of Hips	Fusion		Failures	Percentage of Fusion	End Result Unknown
		After First Operation	After Second Operation			
Entire series	72	41	11	17	75	3
Hips immobilized 2 to 8 years before fusion	43	25	6	9	72	3

TABLE II

RESULTS AS TO TYPE OF ARTHRODESIS

	Solid Fusion	Failure	Unknown
Intra-articular	29	10	2
Extra-articular	23	7	1
Total	52	17	3

same patients had had subtrochanteric osteotomies for correction of a deformity, and it is possible that this may have contributed to their eventual solid arthrodesis.

As regards the local lesion, these results are not unsatisfactory; yet, when we consider the individual as a whole, this form of treatment must be classified as poor, because of the extreme secondary changes which occur in these extremities, subjected to years of immobilization and inactivity. As a rule, the end-result studies showed these patients to have extremities which were several inches shorter, atrophied, and with knees so relaxed that lateral motion often equaled the degree of flexion and extension (Figs. 1-E, 2-G, and 4-A). The long bones were often so fragile that spontaneous fractures were not infrequent. Occasionally, genu valgum and medial or anterior bowing of the tibia were also seen. In short, these individuals were as disabled from these secondary complicating factors as

TABLE III

RESULTS AS TO TYPE OF GRAFT USED

	Solid Fusion	Failure	Unknown
Tibial graft	17	6	
Iliac graft	20	7	
No graft	1	1	
Trochanteric	2		
Iliac with calcium insufflation	2		
Osteoperiosteal	2		
Subtrochanteric osteotomy only	1		
Combination of procedures	7	3	
Total	52	17	3

FIG. 16-A
R. L., male, aged six. Tuberculosis of neck of femur.

FIG. 15-C
Five years after operation.

FIG. 16-B
Three years after removal of sequestrum. Note involvement of acetabulum and capital epiphysis.

FIG. 16-D

FIG. 16-D
Showing tuberculosis of lower portion of fifth lumbar vertebra. Spine fusion had been performed two years before hip fusion. This case demonstrated another good reason for use of a short graft for spine fusion in tuberculosis.

TABLE IV

SHORTENING RESULTING FROM PROLONGED IMMOBILIZATION

Period of Immobilization	Number of Hips Involved	Maximum Shortening (*Inches*)	Average Shortening (*Inches*)
2 to 8 years (Average, 4 years)	43	7	2.7
3 years or more	24	7	3.3

they originally had been from the hip-joint tuberculosis itself. Of forty-three hips which were completely immobilized for from two to eight years, twenty-eight showed shortening of from two to seven inches. There was an average fixation time of four years in the forty-three patients, with an average shortening of 2.7 inches (Table IV). In twenty-four patients immobilized three years or longer, an average shortening of 3.3 inches was found. The degree of shortening, in some instances at least, seemed in direct proportion to the period of complete immobilization. Eleven patients showed shortening of four inches or over, which is certainly enough to be classified as a major deformity and handicap. One patient, immobilized for eight years, showed shortening of seven inches (Fig. 4-A). Other

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case S. D., aged twelve years. Photograph of patient, showing seven inches of shortening following eight years of plaster immobilization. Excellent arthrodesis of the hip had been obtained.

Fig. 4-B: Anteroposterior view of the corresponding knee joint, showing complete destruction of the lower femoral epiphyseal line and only a small marginal remnant of the upper tibial epiphyseal line. The upper fibular epiphyseal line remains open.

TUBERCULOSIS OF THE HIP IN CHILDREN

Certain Roentgenographic Manifestations, Secondary Changes in the Extremity, and Some Suggestions for a Program of Therapy*

BY H. R. MCCARROLL, M.D., AND R. D. HEATH, M.D., ST. LOUIS, MISSOURI

From the Shriners' Hospital for Crippled Children and the Department of Surgery, Washington University School of Medicine, St. Louis

Tuberculosis of the hip in children, despite years of study and varied types of management by innumerable investigators, still stands today as one of the most difficult problems encountered in working with crippled children. In these cases, the ultimate aim for the optimum end result can be simply stated as arthrodesis of the hip; but this is where the trouble begins. To accomplish arthrodesis in a young child early enough to prevent massive destruction of all bone structures in the region of the hip, and to prevent the extreme secondary changes in the extremity which result from prolonged fixation, is no simple task. It is with this aim in mind, and with the desire to stress the extreme secondary manifestations frequently encountered in these extremities, that this presentation has been undertaken. It is based on a study of eighty-six cases at the St. Louis Unit of the Shriners' Hospitals for Crippled Children.

The various clinical manifestations of tuberculosis of the hip are well recognized. We do wish, however, to show two types of early involvement which may be encountered. Phemister and Hatcher, in 1933, in their classical presentation of the pathological changes in tuberculous arthritis, stated that, in the majority of cases, the initial osseous invasion of the hip occurred in the juxta-epiphyseal region of the neck of the femur. In those of our cases in which the early osseous lesion could be determined, the cancellous bone on the acetabular side of the joint was more frequently involved than the metaphyseal region of the femoral neck. A typical case with primary involvement of the acetabulum is shown in Figures 1-A to 1-F. We have, however, seen an occasional case in which the initial lesion occurred in the metaphyseal region of the femoral neck (Fig. 2-A). Such lesions, although they may be slower in progression, usually result in the same massive destruction of the hip joint as shown in this case, and present an equally difficult problem. In most of the cases seen in this Clinic, the disease had advanced to such a degree that it was impossible to state whether the initial invasion was synovial or osseous in nature, or on which side of the joint space the initial osseous invasion had occurred. From a purely practical standpoint, this is of little importance, since total destruction of the joint almost invariably follows either type.

The onset of the disease in very young children, two to five years of age, is not uncommon. There is usually little resistance on the part of these individuals to the infection, and massive destruction in the joint follows very rapidly. Also, in these children, bone development is still in its infancy, and we have very poor structures with which to undertake surgical fixation of the joint. Because of this fact, it was our policy, prior to 1940, to maintain continuous and complete immobilization in plaster-of-Paris spicas until the age of eight or nine years. This age was chosen arbitrarily as the age when bone development was sufficiently advanced so that arthrodesis of the hip could be reasonably expected after insertion of a bone graft by one means or another. Our other theory, in following this plan of treatment, was that surgery should be postponed until the destruction had reached its maximum point, and the development of an area of increased bone density about the defect had shown some attempt to limit the process (Figs. 1-B and 2-C). This line of

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1947.

Fig. 5-A

Fig. 5-B

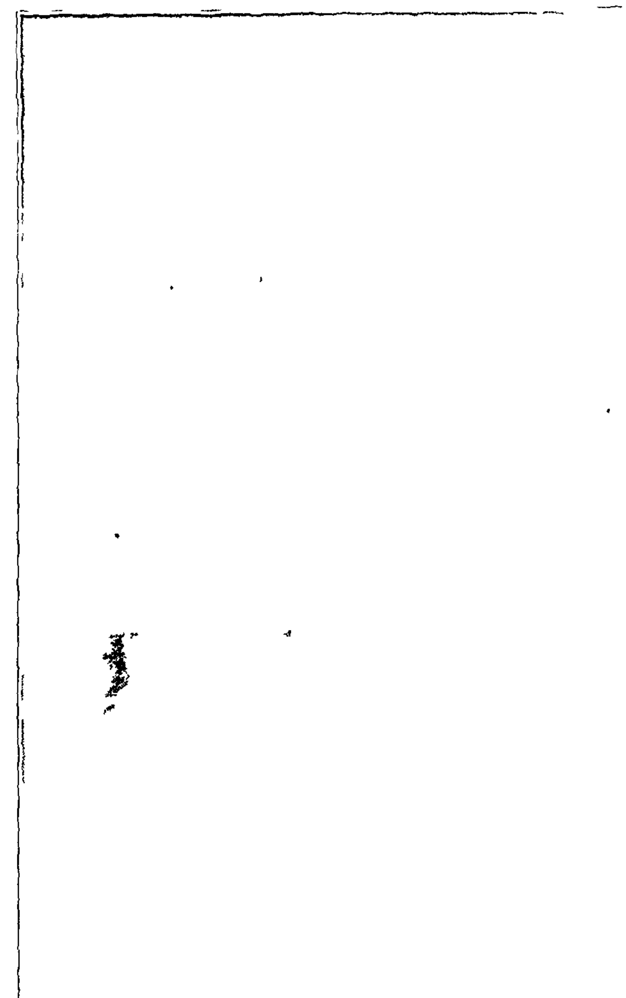

Fig. 5-C

Fig. 5-A: Case S. L., aged five years. Very early tuberculosis of the left hip. Intra-articular arthrodesis was performed six months later with a heavy tibial graft.
Fig. 5-B: Six months after the arthrodesis, showing complete absorption of the graft opposite the joint space and extension of the destructive process.
Fig. 5-C: Four and one-half years after operation. There had been some filling in of the process, but arthrodesis had not yet occurred. Motion was still demonstrable at this time and two draining sinuses persisted. With the degree of healing shown, it is possible that arthrodesis may ultimately occur; but, if it does, the intra-articular arthrodesis cannot be given credit for the fusion

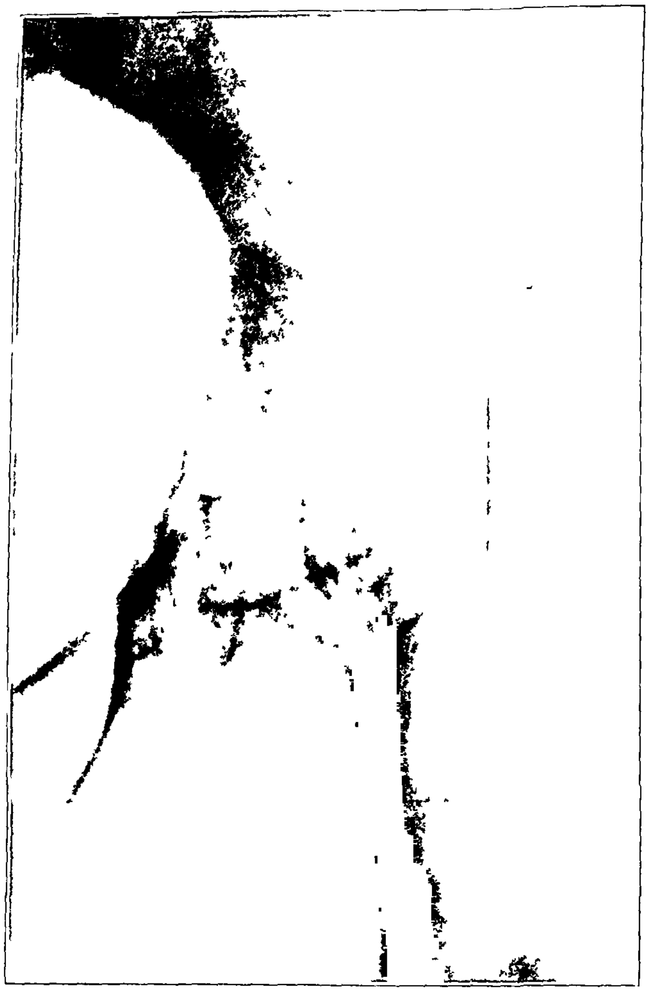

Fig. 1-D

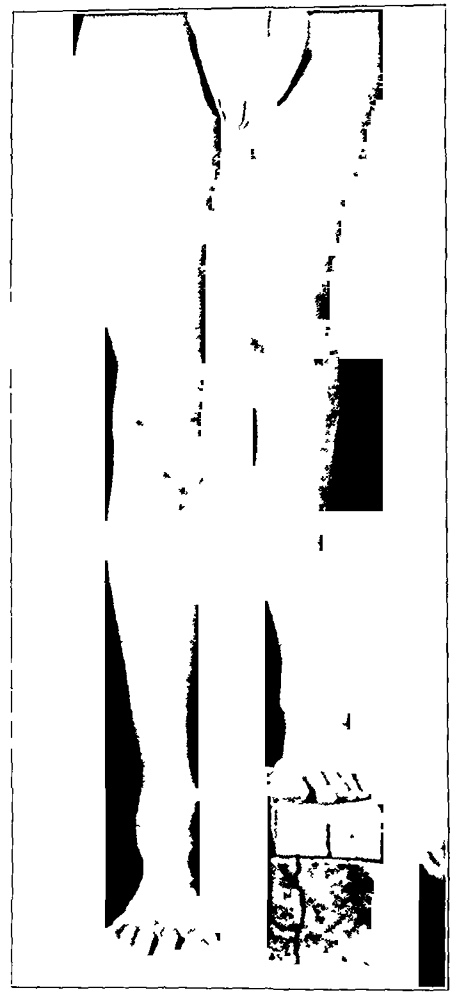

Fig. 1-E

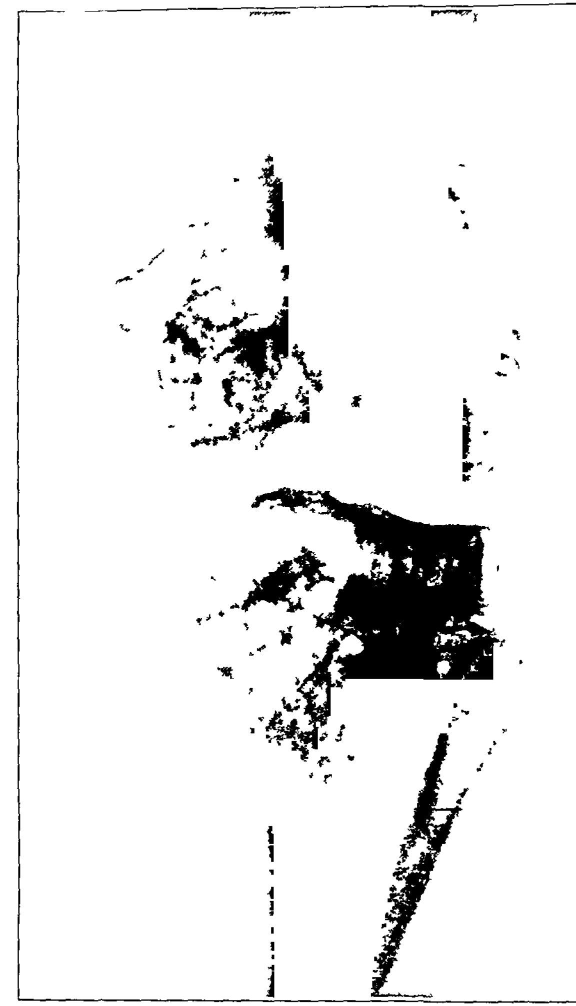

Fig. 1-F

Fig. 1-D: Showing excellent arthrodesis, fifteen years after onset and nine years after operation.

Fig. 1-E: After six years of plaster fixation, shortening of five and one-half inches was obvious Excellent arthrodesis had occurred Patient had moderate relaxation of the knee joint and medial bowing of the tibia

Fig 1-F: Roentgenographic appearance of knee joint after six years of plaster fixation, showing the complete destruction of the epiphyseal lines and marked changes in these regions.

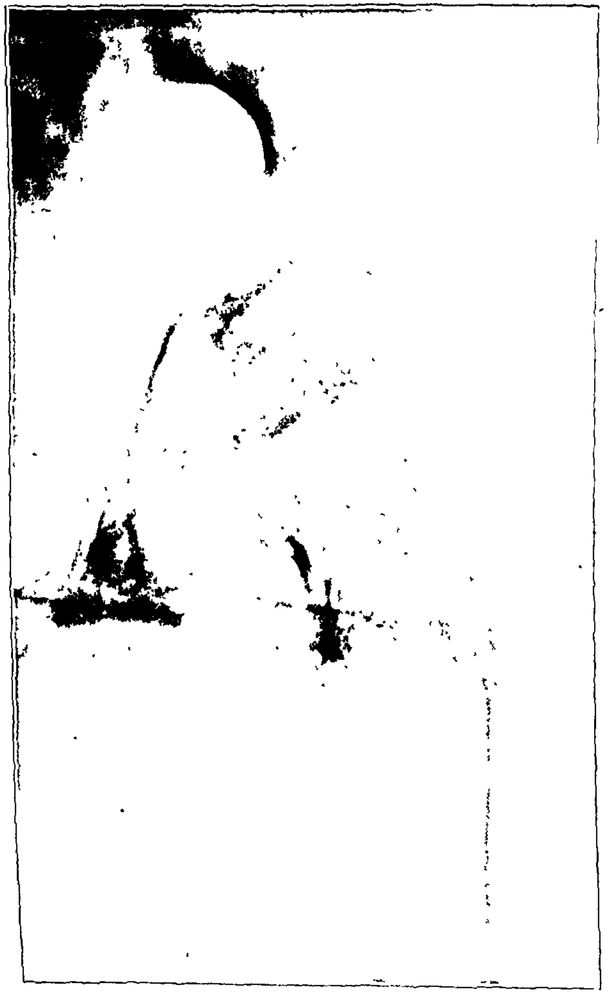

Fig. 7

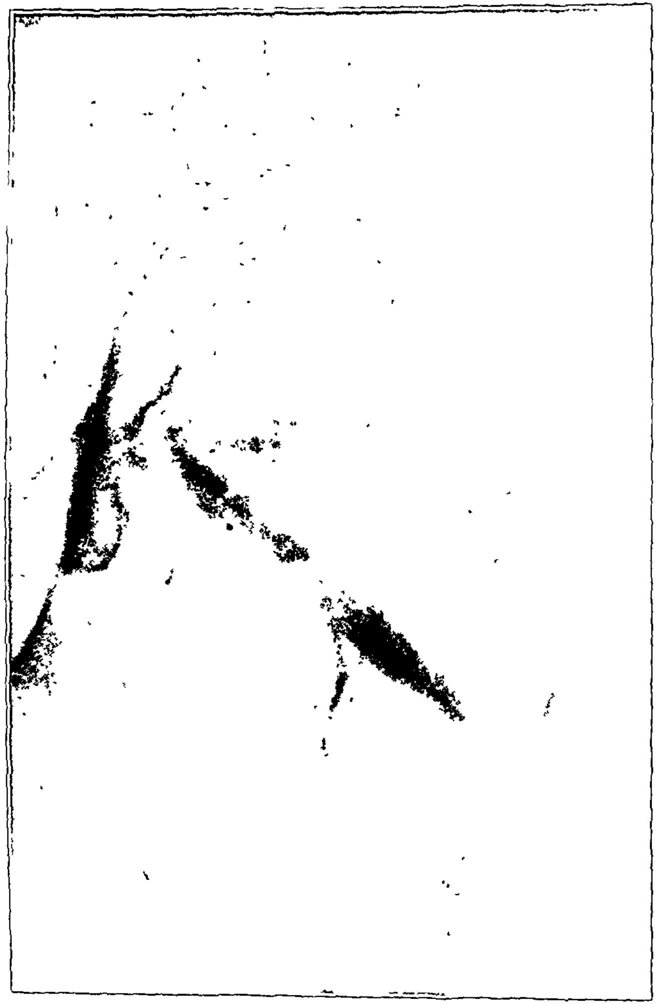

Fig. 8-A

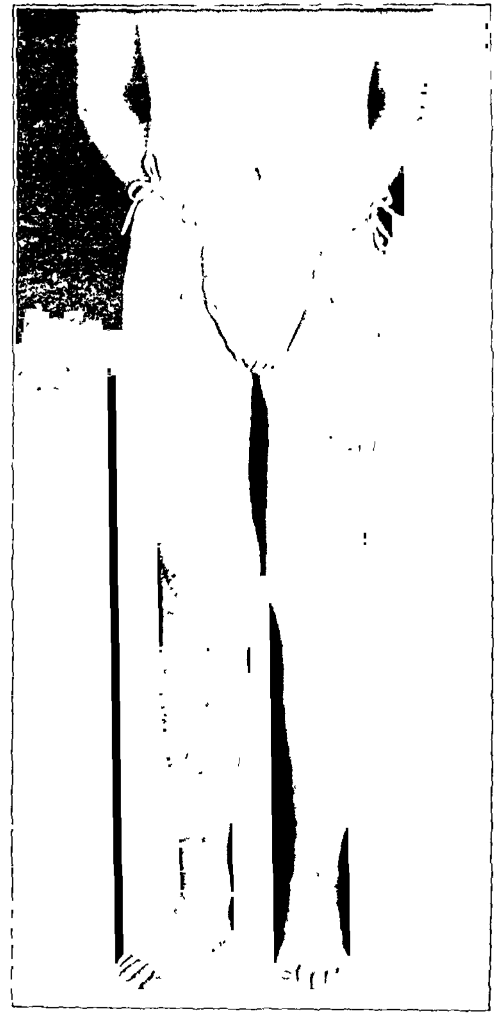

Fig. 8-B

Fig. 7: Case P. K., aged thirteen years. One year after Brittain type of arthrodesis for early tuberculosis of left hip. There was complete absorption of the mid-portion of the tibial graft, which was probably due to invasion of the graft by tuberculous granulations. At the time of operation, no abscess was encountered, and it was thought that the graft had not entered tuberculous tissue.

Fig. 8-A: Case D. S., aged eleven years. Roentgenogram of hip one year after Brittain arthrodesis. At the time this graft was inserted, a large tuberculous abscess was encountered, and the graft unquestionably entered the joint space. There has now been complete absorption of the medial portion of the graft, due to invasion by the tuberculous process. In spite of this lack of fixation, the joint is symptom-free, and weight-bearing with the aid of crutches is permitted.

Fig. 8-B: Even though solid arthrodesis of the hip has not occurred, the length and contour of the extremity have been maintained, and the patient is active with the aid of crutches.

FIG. 2-E

FIG. 2-F

Fig. 2-E: Ten years after onset and three years after arthrodesis, the bone graft had disappeared and there was no evidence of bony union. The defect in the acetabulum and in the femoral neck, however, had filled in considerably.

Fig. 2-F: Twelve years after onset and five years after arthrodesis, complete healing had taken place. The joint space was obliterated and the entire cavity was filled with new bone.

Fig. 2-G: Photograph of D. R. at age of fourteen, after five years of plaster immobilization. Shortening of four inches was still present three years after epiphyseal arrest in the normal extremity.

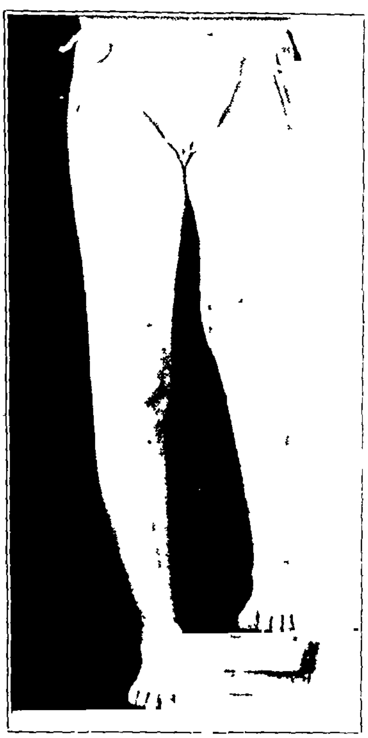

FIG. 2-G

for arthrodesis, satisfactory results were obtained in thirty-one instances. Of the thirty-one satisfactory fusions, twenty-five occurred following the first attempt, while six hips required a second operation. There were nine failures in this group; the results were unknown in three.

In the entire series, arthrodesis has been attempted in seventy-two cases in which adequate follow-up studies have been possible and in which arthrodesis has been delayed for varying periods, according to the age of the patient. These follow-up studies have extended over periods which have varied from three years to twelve years. The results in this entire series are shown in Table I; the percentage of satisfactory fusions is almost identical in the two groups. Tables II and III show results according to the type of arthrodesis and the type of graft used. Satisfactory results in 75 per cent. of the cases is a higher average than in most reports in the literature. There may be two explanations for this higher percentage. First, no adults are included in this series, and it is possible that complete obliteration of the joint space may be more difficult to obtain in adults. The second factor may be the length of follow-up studies in these patients. Many patients, classified as "failures" four to five years after operation, showed excellent results and solid arthrodesis eight to ten years afterwards (Figs. 3-C and 3-D). The length of follow-up is, therefore, definitely important in determining the percentage of solid fusions. In the interval, many of these

cases, and dissolution of the graft promptly occurred in all four cases (Figs. 5-A to 5-C). In only one of the four cases has solid fusion resulted, while in another, some indication of possible ultimate arthrodesis is evident after four and one-half years. Difficulties encountered in these four cases were such that we did not consider the continuation of such a policy justified.

Our next move was the use of a massive extra-articular tibial graft, bridging the joint space from the wing of the ilium to the greater trochanter. A hole was cut in the denuded ilium well above the hip joint, into which the proximal end of the graft was wedged. The distal end of the graft was placed in a groove, cut between the greater trochanter and the base of the femoral neck. In some instances, the entire greater trochanter was removed, the graft was interposed, and both were anchored to the shaft again by means of threaded wires. Bone chips from the tibia and from the ilium were scattered about the tibial graft to fill the defect between the graft and the ilium above the joint level. Here again, however, the results were not encouraging, and the graft often failed to serve as a permanent support (Figs. 6-B and 6-C).

At this time the Brittain arthrodesis was reported in the American literature [4] as being quite satisfactory, and we turned to it in the hope that this might serve as a solution to the problem. Six such operations have been done in patients with early lesions, and we are still not convinced that this is an entirely satisfactory answer for the management of the early tuberculous hip. The following technical difficulties have been encountered in performing the operation in young children: (1) The placement of the osteotome and the large tibial graft into the small area of the ischium below the acetabulum, without entering the hip joint and without placing the graft in the area of the obturator foramen, is difficult. With the former, the fusion becomes intra-articular in type; and with the latter, a smaller bed of bone is available for fixation of the tibial graft. (2) The distal fragment of the femur should be completely displaced medially, so that this fragment completely bridges the span of tibial graft between the ischium and the trochanteric area of the proximal fragment. This has proved to be a difficult accomplishment in young children, even when the entire circumference of the limiting periosteum has been cut. Such displacement of the distal fragment and the maintenance of this position are more difficult in young children than in adults, even when the extremity is widely abducted. A review of the cases reported in the literature shows that other authors have apparently had similar difficulties.

Follow-up studies on this series of six cases are not available at this time. The youngest patient in this group is four years of age and the oldest is thirteen years. Four of them have been followed for over one year. In two of these cases (Figs. 7 and 8-A), absorption of a portion of the graft had occurred by the end of the first year. This was undoubtedly due to invasion by tuberculous granulation tissue. In two other cases (Figs. 9 and 10-A), the graft seems to be united at each end, and the patients are walking with the aid of crutches. Yet, the degree of fixation is not very great, and there has been little, if any, change in the appearance of the hip joints. Over a period of years, however, complete obliteration of the joint space may occur. In this series of seventy-two hips upon which arthrodesis has been attempted, many hips, as stated previously, could be classed as solidly fused, after follow-up studies of eight to ten years, in which the results would have been classed as failures after four to five years.

An important point in the selection of cases suitable for the Brittain arthrodesis is to make sure that the portion of the ischium to be used has not been invaded by the tuberculosis. Unless normal bone is present at this point for the insertion of the bone graft, an extra-articular type of arthrodesis is impossible, and the primary purpose of the operation has been lost. Brittain states that tuberculous disease more frequently extends upward into the ilium than downward into the ischium; in fact, he states that the latter is extremely rare. Other authors [2,4] have verified this statement. This may be true in the very early phases of the disease; but, if the process has been present for a moderate length of

FIG. 3-A

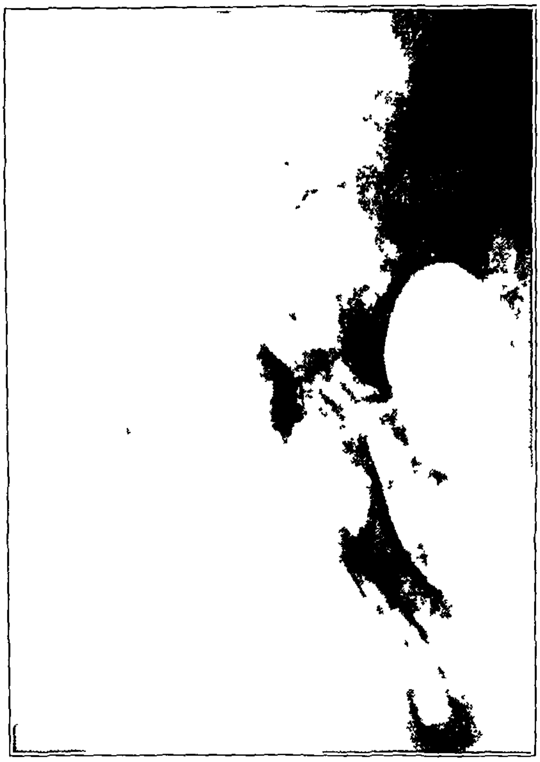

FIG. 3-B

Fig. 3-A: Case A. D., aged three years. Roentgenogram shows massive destruction of the right hip from tuberculosis. Obviously the primary osseous lesion in a case of this type cannot be stated.

Fig 3-B: Four months later, immediately after an intra-articular type of fusion with the insertion of a massive tibial-bone graft.

FIG. 3-C

FIG. 3-D

Fig. 3-C: Three years later, roentgenogram shows some filling in of the destructive lesion, but complete failure as far as the arthrodesis itself is concerned.

Fig. 3-D: Twelve years after arthrodesis, showing complete obliteration of the destructive lesion and bony trabeculae traversing the entire joint space. Subtrochanteric osteotomy had been performed in the interval.

DISCUSSION

Dr. Robert Perlman, Cincinnati, Ohio: I am in hearty accord with Dr. McCarroll in his idea of attempting to forestall the secondary changes in the extremity, which result from chronic, destructive tuberculosis of the hip and its treatment. Will this problem be solved before a more direct method of approach is made on the tuberculous process itself, comparable to the use of penicillin in osteomyelitis? Can we avoid long periods of immobilization? May we permit early activity and early partial, protected weight-bearing of the involved extremity? Dr. McCarroll may have the answer in his suggestions of early operation and early activity.

That arthrodesis of the joint is a most suitable form of aid in the arrest of the tuberculous process, is widely accepted. The controversy arises as to which method of arthrodesis best meets the need in any particular case. Dr. McCarroll obtained fusions in 75 per cent. of his cases. About 18 per cent. of these had to have more than one operation. The type of operation varied. Dr. Pease, using Dr. Chandler's method of fusion, obtained successful fusions in 85 per cent. of his cases. A small number of these required second operations. In Dr. Chandler's operation, it appears to be true that the tuberculous focus is collapsed, but is the disease completely eradicated by this procedure? Is it certain that the manipulation at operation does not cause dissemination of the tuberculosis? Is the situation in hip and in knee tuberculosis comparable? In how many cases is there a flare-up after successful fusion, no matter what the type of operation?

We believe the following criteria should be met in the treatment of tuberculosis of the hip:

1. An adequate period of preoperative care.
2. A successful fusion operation, which should provide:
   a. A high percentage of fusion in a relatively short period of time, in order to allow activity as early as possible;
   b. Fusion of the extremity in the optimum functional position;
   c. Avoidance of the tuberculous process as far as possible;
   d. Avoidance of the development of postoperative sinuses.

These criteria are best fulfilled in our hands by the Brittain operation. We intend to give the method a continued trial.

I agree with Dr. McCarroll that the invasion of the inferior aspect of the acetabulum occurs not infrequently, but it does not always involve so much of the ischium as to contra-indicate the Brittain operation. With traction, medial displacement of the distal fragment is not difficult. Complete circumferential division of the femoral periosteum is not necessary in order to displace the distal fragment medially; and displacement is necessary in the Brittain operation. If the ischium is involved, should osteotomy be performed as a compromise? This procedure necessitates rest during healing, and it may also in itself lead to fusion.

Dr. H. D. Morris, New Orleans, Louisiana: Heretofore, on our Service at Charity Hospital and in the Louisiana State Crippled Children's work we have been reluctant to enter the area of tuberculous involvement and have confined ourselves, as far as possible, to extra-articular methods of fusion in tuberculous hips. However, the experience of Dr. Pease with the Chandler type of fusion should allay any hesitancy on the surgeon's part to combine intra-articular with the extra-articular technique, for certainly three failures in twenty-eight arthrodeses speak for the technical efficiency of this method. The ease and saving of time in a direct lateral approach to the involved hip should appeal to most operators, and the trochanteric graft offers an abundance of osteogenic material. Dr. Pease mentions one point, in the general treatment of tuberculous patients, which I would like to emphasize,—that is, the routine guinea-pig inoculation with the urine of all patients under active treatment every six months. Unless this is done, I am sure that many concomitant tuberculous kidneys, which exhibit no urinary symptoms, will be overlooked. The use of intrapelvic obturator neurectomy as a preliminary procedure to arthrodesis of the hip offers a new and unique attempt to prevent the occurrence of flexion and adduction contractures, which, in our own experience, have occurred all too frequently, even following excellent original hip surgery in which there was apparently satisfactory arthrodesis.

I think we are indebted to Dr. McCarroll for again stressing the extreme secondary manifestations, particularly the shortening which results after the prolonged fixation that is generally used in the treatment of tuberculous hips prior to fusion. It has been customary on our Service to use the same criteria as mentioned by Dr. McCarroll and to delay surgery until destruction has reached its maximum and an area of increased bone density about the tuberculous defect can be seen in the roentgenogram, indicating that the individual has shown some attempt to limit the tuberculous process. Stimulated by his observations, I rapidly reviewed five cases of adult tuberculous hips treated on our Service, in which cessation of growth had occurred, and I found that the maximum shortening was five and one-half inches and the average shortening three inches. I heartily agree that it behooves those of us who are doing work with crippled children to rationalize our initial treatment of tuberculosis of the hip in an attempt to prevent these extreme secondary changes, which are frequently as disabling as the primary disease.

I would like to show slides of two cases in which the Brittain type of arthrodesis was performed. In both instances, the medial portion of the graft was inserted into the ischium, which was definitely involved in the tuberculous process. The first patient was thirteen years of age at the time of arthrodesis and now, fourteen months following the operative procedure, has an excellent result with no evidence of involvement of the

FIG. 4-C

FIG. 4-D

Fig. 4-C: Low-power magnification of lower femoral epiphyseal line of the involved extremity, after eight years of plaster fixation. Only a remnant of the epiphyseal cartilage remains, and this lies parallel to the long axis of the bone and disappears entirely a short distance below the surface.

Fig. 4-D: Low-power magnification of normal lower femoral epiphyseal line in the uninvolved extremity.

major operations were often necessary in an attempt to compensate for this shortening, but their consideration is not within the scope of this discussion.

We were at a loss to account for the extreme degree of shortening which occurred in these patients. The upward displacement of the extremity as a result of the destruction at the hip joint, and the complete loss of the upper femoral epiphysis, which accounts for only 12 per cent. of the growth of the lower extremity, could not possibly explain the extreme shortening which followed. It finally occurred to us to take roentgenograms of the other epiphyses of the extremity, and these revealed changes which could easily explain the discrepancy. Premature closure of the epiphyses, with deformity of the epiphyseal plates and metaphyseal areas, was revealed (Figs. 1-F and 4-B). These changes were described by Gill in 1944. Sections for biopsy were obtained from the lower femoral epiphyseal lines in the involved extremity and in the normal extremity of the patient with seven inches of shortening. These revealed only a remnant of the epiphyseal line in the involved extremity (Fig. 4-C), as compared with a perfectly normal epiphyseal structure on the other side (Fig. 4-D).

As stated previously, of forty-three hips treated by prolonged preliminary plaster fixation and rest, solid fusion occurred in thirty-one instances after surgical arthrodesis by means of bone grafts. However, the secondary changes resulting in the extremities were so serious that it seemed unwise to continue this plan of therapy. We decided, therefore, to attempt earlier operative fixation in every instance where the general condition of the patient would permit. Plaster fixation of the hips was used for approximately six months after the diagnosis had been established, in order to permit the early acute symptoms to subside and also to improve the general condition of the patient as much as possible. This was then followed by attempted arthrodesis of the hip. While it was clearly understood that early intra-articular arthrodesis was inadvisable and unsuccessful in the majority of instances, we still attempted four such operations. Draining sinuses followed in three of the

DR. A. BRUCE GILL, PHILADELPHIA, PENNSYLVANIA: Forty years ago, when I began the practice of orthopaedic surgery, the accepted method of treating tuberculosis of the hip in children was by prolonged fixation in plaster casts. Observation over a period of years demonstrated that a frequent result of this method of treatment was a very marked shortening of the entire lower extremity,—often as great as four to six inches. We thus learned that prolonged encasement in plaster casts produced marked atrophy of skin, muscles, and bones, and prevented normal growth. The use of Buck's extension, enforced recumbency, prevention of gross movements of the hip joint, and exposure to sunshine has brought about happier results.

My own opinion is that we must consider tuberculosis of the hip as a general disease with a local manifestation, and that it can be arrested only through increasing the natural resistance of the child to this infection. Many of us have frequently observed that attempts to fuse a tuberculous hip in the acute stage of the disease do not result in fusion and an arrest of the disease process. On the other hand, the disease continues to spread and, not infrequently, the wound eventually breaks down and becomes infected with pyogenic microorganisms. It always appears particularly unreasonable to attempt to fuse a hip when the disease involves the ilium. How can prevention of motion by fusion cure the disease in a bone where there is normally no motion?

Fusion, in my opinion, is indicated only after the natural resistance of the child has gained mastery over the disease, and after the acute stage of the process has passed. I think the most suitable time for operation is after the child has reached his tenth year of age, provided the acute manifestations of the disease have disappeared. *The object of fusion is not to cure tuberculosis of the hip, but to prevent local recurrence of the disease and to prevent or to correct deformity of flexion and adduction.*

About twenty years ago I published a paper ("Pathological Dislocation of the Hip", *Southern Medical Journal*, **22**:207–212, 1929) in which it was demonstrated that intra-articular fusion can be accomplished in old cases of tuberculosis without danger of causing recurrence of the disease. These operations were done at a time when orthopaedic surgeons, for the most part, were fearful of operating upon a tuberculous joint.

I should like to emphasize again that operation upon a local focus will not of itself cure a general disease, and it will not cure the local manifestation of it, unless the resistance of the child becomes sufficiently developed to bring about an arrest or cure of the morbid process. We do not know of any short cut for the cure of tuberculosis. Individuals affected by this disease must, throughout all their lives, maintain their bodily resistance at a high level to prevent local manifestations of the disease in various parts of the body.

DR. C. N. PEASE, CHICAGO, ILLINOIS (closing): I did not come here to discuss the Brittain operation. I came here to show what I believe is the best approach to an active tuberculosis in the hip joint. I think the number of cases shown here this morning bear out my point. I had a good many more slides to show, several of which illustrate eradication of the active tuberculous areas.

In reply to Dr. Perlman, the knee joint is just as much a weight-bearing joint as the hip joint, yet there is no hesitancy on the part of any orthopaedic surgeon about fusing a tuberculous knee joint. It is true that you may run into active disease and that you may expect drainage, but not any more so than in a tuberculous knee. We feel that we give our patients adequate preoperative care before starting this procedure. We have had none go into acute surgical shock. I remember no case where a blood transfusion was performed at the time of operation. This operation is simple; it takes about thirty minutes. The obturator-nerve section is done as a preliminary and takes only ten or fifteen minutes.

I think Dr. Morris and Dr. Barr spoke of waiting until the tuberculous process became stationary. If you wait for that, before you do your fusion, you will wait a long time. Dr. McCarroll showed that some of these patients had been five or ten years in plaster—so long that shortening of the leg from five to seven inches had occurred—and still the process was active. We get our children into the best possible condition, with the blood count up and the sedimentation rate down; when they reach this point, we do our surgery. One young boy had had the disease for five years and was treated elsewhere by so-called "corrective measures". We felt that sufficient time had been spent on this type of therapy. His condition was as good as it was going to be. He was operated upon one week after admission to the Hospital. He later became a basketball player and a baseball pitcher and was offered an athletic scholarship at a small Illinois college. It you wait until roentgenograms show a decrease in tuberculous activity, you will wait a long time; and in many of these cases, further destruction takes place.

DR. H. RELTON MCCARROLL (closing): In answer to Dr. Gill, I realize that none of the work presented is original. Most of these procedures and the types of arthrodesis presented have been done over and over again. We know that many years ago Dr. Hibbs discontinued prolonged plaster immobilization of tuberculous hips, because of the marked shortening which resulted in the extremities, but most of us are stubborn enough to believe something much more readily after we have had an opportunity to try it ourselves.

Fig. 6-A

Fig. 6-B

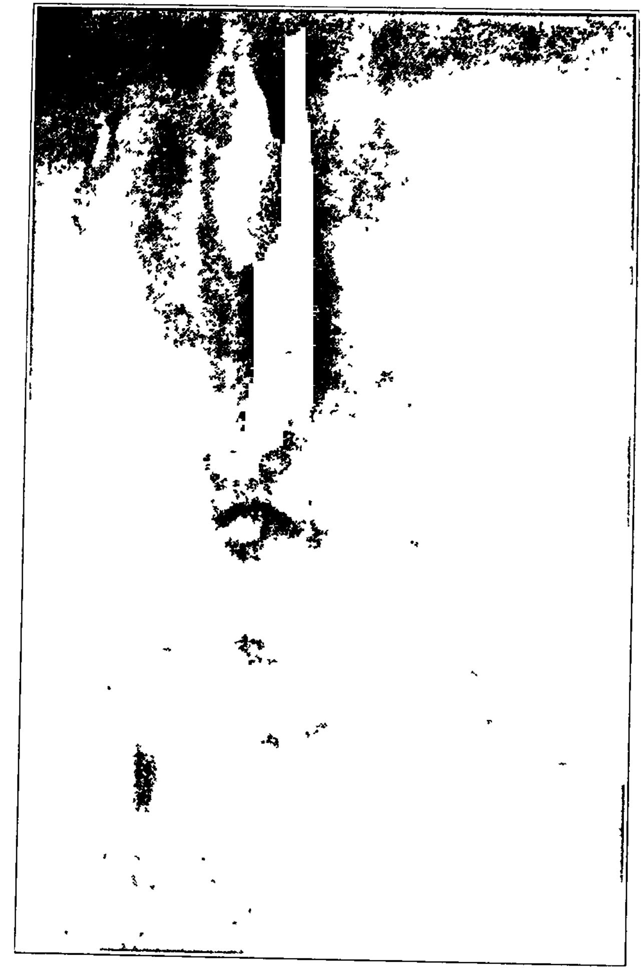

Fig. 6-C

Fig. 6-A: Case V. F., aged six years. Tuberculosis of the right hip, three years after onset of symptoms.

Fig. 6-B: Roentgenogram, showing hip after extra-articular arthrodesis by means of massive tibial graft; this was anchored to shaft below by means of threaded wires which were later removed.

Fig. 6-C: Roentgenogram of hip, four years after arthrodesis. Ultimate solid fusion appeared certain, but pseudarthrosis of the graft was still present. The graft, therefore, had failed to afford fixation.

FIG 1

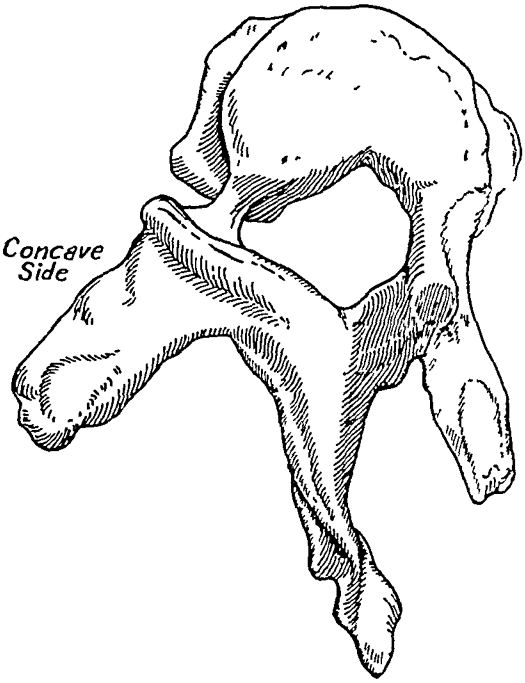

FIG. 2

Fig. 1: Showing the typical appearance of wedging at *A*, and also changes indicating rotation of bodies as a whole. At level *B* there is no rotation, and the outlines of the pedicles are disposed symmetrically. At level *A* there is rotation; and the outline of the pedicle is visible on the convex side only, and is displaced medially relative to the lateral border of the vertebral body.

Fig 2. A vertebra from the middle of a curve, as seen from above, showing atrophy of the pedicle on the concave side (*According to Broca*)

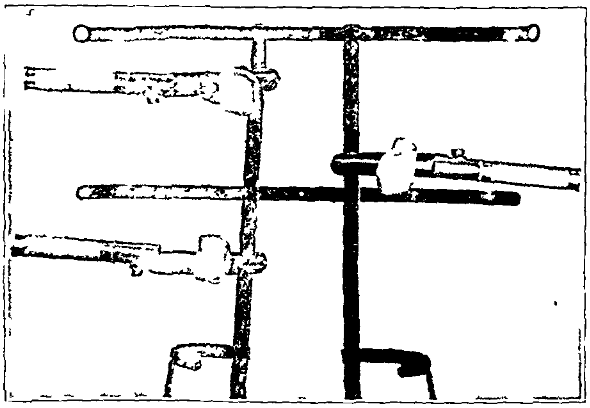

FIG 3

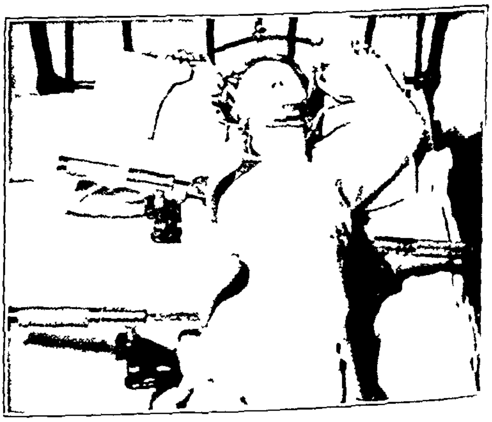

FIG 4

greater resistance to correction of the rotation. Rotation in itself is a complicated deformity, and its precise nature cannot be learned from a roentgenogram. It comprises two elements,—the rotation of the vertebrae as a whole, and the structural distortion of the various parts of each individual vertebra.

It is assumed that, as lateral deviation develops, each vertebra in the affected segment rotates on a vertical axis situated somewhere behind its spinous process. The total rotary displacement in the spine is recognized in roentgenograms as a general asymmetry of the shadows of the pedicles in relation to their corresponding vertebral bodies. Normally, the outlines of each pair of pedicles are seen roentgenographically to be disposed symmetrically toward the lateral borders of each vertebral body (Fig. 1, *B*). If the vertebral bodies rotate,

Fig. 9

Fig. 10-A

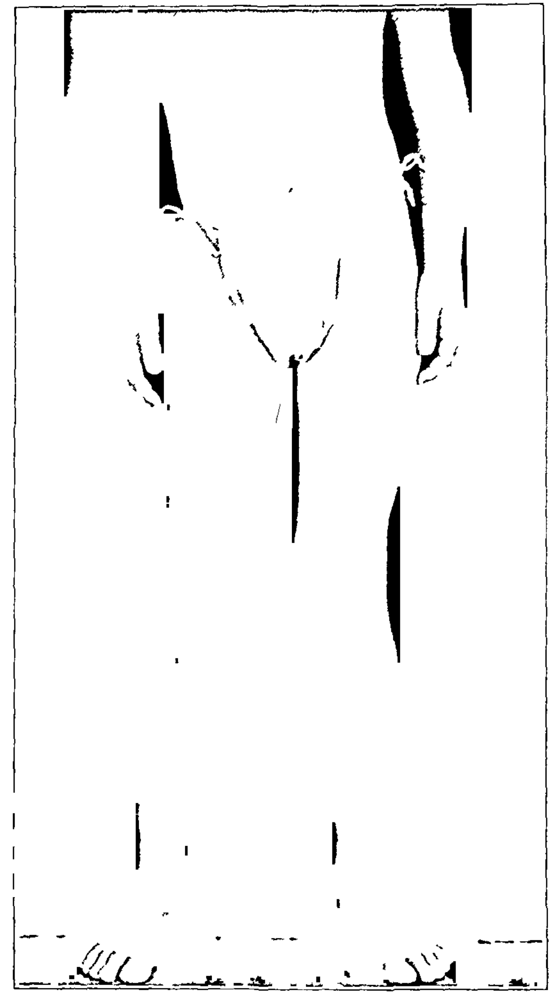

Fig. 10-B

Fig. 9: Case P. D., aged seven years. Appearance of hip one year after Brittain arthrodesis. The graft seems to be anchored at each end and adequate to afford support.

Fig. 10-A: Case J. B., aged seven years. Roentgenogram of right hip one year after Brittain arthrodesis; the graft appears to be firmly anchored at each end.

Fig. 10-B: The length and contour of the extremity have been preserved. Some abduction is present.

FIG. 7-A

FIG. 7-B

Fig 7-A: Case 3. W. B., a boy, aged twelve. Mild degree of wedging and very little rotation.
Fig 7-B After correction of lateral deviation, rotation actually increased.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 4. E. D., a girl, aged thirteen. Mild degree of wedging and rotation.
Fig. 8-B: Showing full correction of both.

time, destruction of the ischium is very common. Of eighty-three patients in this series with adequate roentgenographic studies, extension into the ischium for a significant distance below the acetabulum was present in sixty-three instances (76 per cent.). This obviously rendered these patients totally unsuitable for surgery of this type. As a matter of trial, this operation was performed upon one patient with obvious involvement of the ischium. Follow-up studies on this patient are not yet available.

In spite of these difficulties and considerations, however, the Brittain arthrodesis seems to offer as good a possibility for an early, successful arthrodesis as is available at present. It should be remembered that to attain good arthrodesis of a tuberculous hip in a young child, when the disease is still in the active phase, is a very difficult task, and there is no entirely satisfactory procedure available. When we consider the crippling effect of secondary changes in extremities that have been immobilized for many years prior to arthrodesis, however, we must admit that some form of early operative fixation is justified and should be attempted. It is with this in mind and in an attempt to activate the diseased extremities as soon as possible, that the Brittain arthrodesis will be given further trial. Certainly a procedure of this type offers some hope of our being able to preserve the length and contour of the extremity (Figs. 8-B and 10-B). Since these patients now have active use of their extremities, it seems reasonable to assume that severe secondary changes in the extremities can be prevented. (Compare with Figures 1-E, 2-G, and 4-A.)

An attempt has been made to rationalize early treatment of tuberculosis of the hip from the knowledge derived in this study, which has extended over a period of several years. The young child with a tuberculous hip is immobilized in a plaster spica for a period of six months, during which time an attempt is made to improve his condition as much as possible by adequate diet, rich in milk and vitamins, and by general supportive care. If the general condition is suitable at the end of six months, a Brittain type of arthrodesis is attempted or, if this is not applicable, some other extra-articular type of fixation is done. The patient is again immobilized in a plaster spica for from six to twelve months, depending upon the degree of union of the graft, during which time adequate general care is maintained. Immobilization is then discontinued, and the patient is allowed to become ambulatory with the aid of crutches, and is permitted to use the hip and extremity increasingly. Even if the arthrodesis fails, active use of the extremity is allowed at this time, in order to ensure against damage to epiphyseal structures by prolonged fixation. A second attempt at arthrodesis is postponed until a later date, and use of the extremity is permitted and encouraged during the interval.

In those instances where the patient's condition is not considered suitable for surgery, plaster fixation is maintained for six months in order to allow the acute phase of the process to subside, after which active use of the extremity is permitted and weight-bearing is instituted, if possible. In some instances, deformities at the hip will follow, but these can be corrected more easily than the deformities occurring in the extremity as a whole, as the result of prolonged fixation and inactivity.

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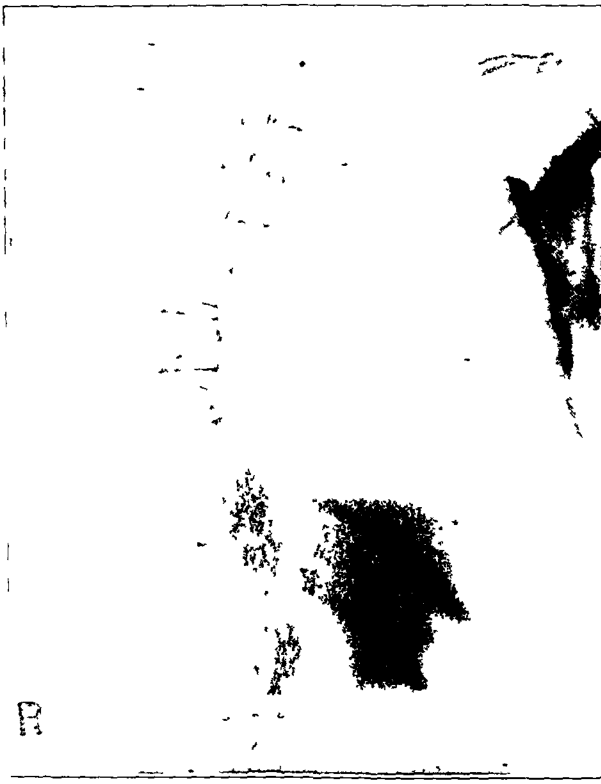
become less distinct and in severe cases may disappear entirely as a displacement in the same direction takes the pedicles away from roentgenographic view.

The second element in rotation, that of structural distortion of the various parts of an individual vertebra, involves particularly the posterior arch. Figure 2 depicts a vertebr taken from the middle of a mild curvature. A salient feature of this distortion is atrophy of the pedicle on the side of the concavity. If the vertebrae are considered in relation to



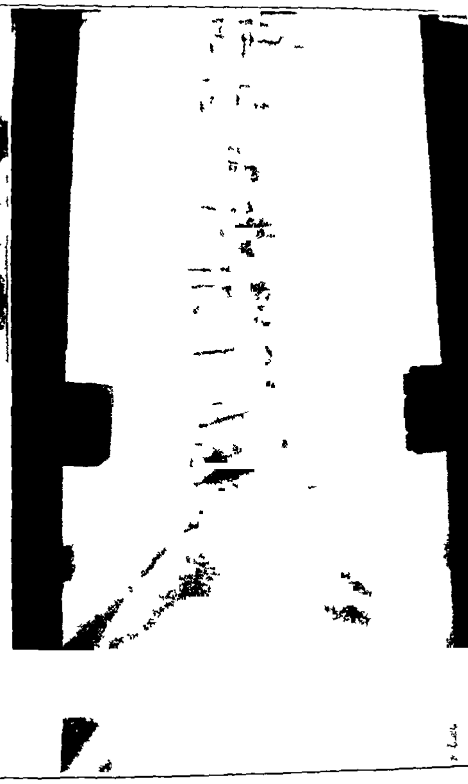


FIG. 11-A FIG. 11-B

Fig. 11-A: Case 7. B. W., a girl, aged fourteen. Mild wedging and moderate rotation.

Fig. 11-B: Improvement in lateral deviation, but rotation is unaffected. Note that corrective pad on right is too low.

FIG. 12-A FIG. 12-B

Fig. 12-A: Case 8. T. C., a girl, aged thirteen. Extreme wedging, rotation, and rib deformity.
Fig. 12-B: Slight improvement in lateral deviation and rotation.

graft. The second patient, in whom arthrodesis was performed at the age of four years, shows definite early extension of the tuberculous process into the graft. It is now seven months since the operation, and the outcome cannot be definitely determined at this time. These cases only re-emphasize the difficulties that Dr. McCarroll has outlined.

Dr. Joseph S. Barr, Boston, Massachusetts: We have heard two excellent papers on the operative technique of fusion of the hip in childhood, when that joint is involved in a tuberculous process.

It is most important to consider not only the operative technique that should be employed, but also the best time for operation. In my opinion, too early operative interference does more to jeopardize a good operative result than do variations in technique.

In the acute or evolutionary phase of the disease process, there is slowly increasing destruction of the joint and adjacent bony structures, as shown by repeated roentgenographic examinations. Abscess formation occurs in about 50 per cent. of the cases, and in certain of these, draining sinuses develop. The general condition of the child reflects this situation, since he does not gain weight satisfactorily, muscle spasm is present about the hip, and blood studies usually show an increased monocyte-lymphocyte ratio. In other words, during this evolutionary phase, there is neither satisfactory local nor general resistance to the disease. Any attempt at fusion during this phase is doomed to a high risk of failure, for the active tuberculous process can destroy bone grafts about the hip joint as easily as it destroys the hip itself. During this phase of the disease, the treatment is, as H. O. Thomas said many years ago, "Rest, uninterrupted, continuous, and prolonged". The duration of this period of conservative treatment varies widely,—in some cases, a few months; in others, several years. When muscle spasm has subsided, when the child is in good general condition, when abscesses have regressed, and when repeated roentgenograms show no increased bone destruction, then we can safely operate with the expectation of obtaining solid fusion in about 70 per cent. of the cases at the first operation, and with the knowledge that we can increase that proportion of successful results to about 90 per cent. by several rather minor operations for the repair of pseudarthrosis in the bone graft.

I am in favor of a properly timed operation on the hip joint itself. The ischiofemoral arthrodesis has not been proved to yield better results.

Dr. Gerald G. Gill, Oakland, California: Dr. McCarroll is to be commended for re-emphasizing the occurrence of premature closure of the epiphyses about the knee in connection with tuberculosis of the hip in children. This is a serious, although not well-known, complication of this disease. In 1944, I reported fifteen cases of this condition. In every case, there was extreme decalcification of the bones of the affected extremity. This decalcification must be due to the long-continued inflammatory process in the hip and to disuse, consequent upon the long period of immobilization. Decalcification to this degree must radically change the physical structure of a cartilage plate, and make it more susceptible to trauma.

It is my belief that in decalcified bone, the cartilage plate probably exists as a fragile curtain between the two relatively fluid media. In addition, the decalcified bone is soft and bends easily. This bending may cause sufficient changes in the intramedullary pressure to rupture either the cartilage plate or the small blood vessels going into it. These changes will occur in the region of the greatest stretch, at or near its center. In three of the cases reported, there was diaphyseal fracture, followed by arrest of growth at both centers about the knee. The closure of both centers following the fracture of one bone indicates that trauma, not fracture, is the inciting cause of the arrest of growth. Therefore, unless it is found to be absolutely necessary, long periods of immobilization in the spica casts, prior to surgery, should be avoided before the cessation of growth, and arthrodesis should be performed as early as the patient's general condition permits. During the arthrodesis operation, at subsequent osteotomies, and during each change of cast, the limb should be handled with extreme care, particularly if the limb shows tenderness.

It is interesting to note that many years ago, Dr. Hibbs began to treat tuberculosis of the hip by early fusion, early weight-bearing in a walking cast, and early mobilization. Ten of the cases of premature closure, originally reported by me in 1944, were found from an analysis of 150 cases of tuberculosis of the hip in children, treated at the New York Orthopaedic Dispensary and Hospital. That such a small number of these complications occurred in such a large number of cases would seem to suggest that this is the treatment of choice.

The early recognition of premature closure is also of extreme importance, since it will allow early institution of those procedures necessary to prevent great inequality in length from the unopposed growth of the normal leg.

For this reason, I believe that, in every case of tuberculosis of the hip in children, frequent measurements of the long bones should be made by the use of scanograms. In those instances where it appears that there is extreme decalcification, markers should be placed in the shafts of each of the long bones and new scanograms should be taken at six-month intervals, so that the growth from each center may be accurately measured. This permits early decision as to the proper procedures necessary to give equalized length to the legs, satisfactory bodily proportions, and adequate final height.

FIG. 14-A

Fig. 14-A: Case 10. G. G., a boy, aged five. Another example of idiopathic scoliosis at an early age.

Fig 14-B: Good correction, but rotation is still severe.

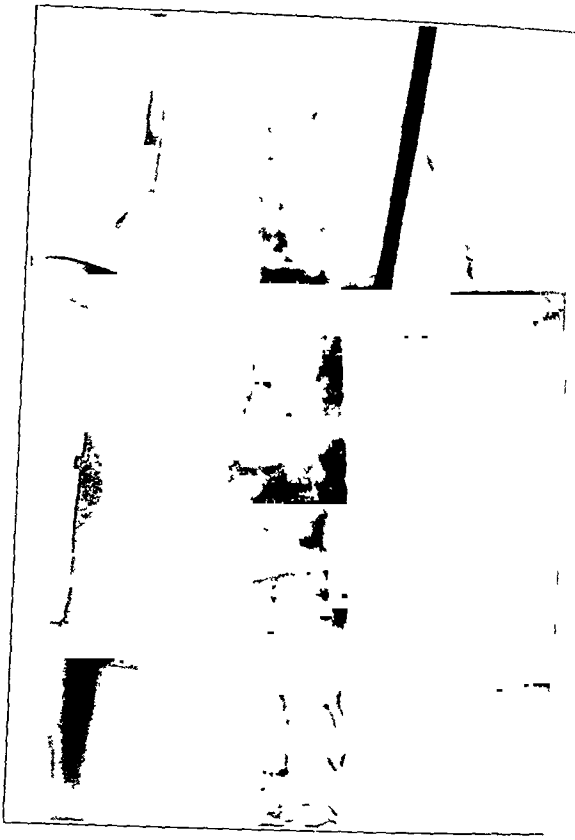


FIG. 14-B

can be controlled. These screw pressure pads (Fig. 3) are attached to the horizontal bars of the Thomas frame. One pad is applied to the chest wall, opposite the point of maximum curvature. Two others are applied on the opposite side,—one against the pelvis and the other against the chest wall at the upper extremity of the curve, usually near the axilla Counterpressure will thus prevent the production or accentuation of secondary curves.

PROCEDURE

The patient is put on the frame for three or four days, in order that he may become accustomed to it. Fixed extensions are then applied to the legs, and weight traction to the head, commencing with about ten pounds. The head of the bed is raised two feet. After two days the pressure pads are applied and are brought to bear gently on the trunk (Fig. 4).

The weights are increased by about one pound daily, and, although a maximum of about twenty-five pounds for the younger patients and thirty pounds for the older patients is aimed for, the comfort of the patient is the governing factor in determining the amount of weight used. The screws are tightened twice daily. The amount of pressure exerted by the pads is a matter for judgment, but it should never be sufficient to produce discomfort Roentgenograms are taken every two weeks while the correcting forces are in operation.

The nursing is simple. Release of the screws and weights once daily for skin toilet suffices.

RESULTS

Fifteen cases of idiopathic scoliosis have been treated by this method, and the results are shown in the form of paired roentgenograms, taken before and after correction Of these fifteen patients, three benefited little from the treatment for one or the other of the following reasons:

1. In one (Figs. 17-A and 17-B) the curve was too high in the thoracic region. A pad could not be applied opposite the point of maximum curvature, and counterpressure was impracticable.

IDIOPATHIC SCOLIOSIS

A METHOD OF CORRECTION *

BY GORONWY E. THOMAS, M.CH. (ORTH.), F.R.C.S. (EDIN.), LIVERPOOL, ENGLAND

Idiopathic scoliosis is a most discouraging condition to treat. Its etiology is so vague and its course so variable that the prognosis in any given case becomes difficult or impossible to determine. In possibly the majority of patients, the degree of deformity will be limited by a spontaneous arrest of the process. In others, the curvature will increase during the period of growth and will produce not only intractable deformity, but also a deterioration in general health.

It can be assumed, therefore, that any patient allowed to go untreated may become worse, and that efforts should be directed toward preventing an increase in the deformity and toward correcting, as far as possible, the condition which is already present.

DISADVANTAGES OF PRESENT METHODS

Many methods and devices have been suggested for the correction of the deformity. Since most of these have failed, there is as yet no satisfactory method of treatment. The application of the commonly employed corrective plaster jackets tends to be exhausting to the patient and laborious for the surgeon. Moreover, the results, even after long periods, are too uncertain a reward for the labor and endurance involved. Treatment by turnbuckle jackets, a method revived in the last few years, has the added disadvantage of tending to produce or to accentuate a secondary curvature. In attempting to correct the deformity, the disproportion between the effort involved and the response obtained has formed the basis of the statement once made that "the treatment of scoliosis is a perpetual lesson in humility".

It was in an attempt to reduce this disproportion that the method here described was developed. In this presentation, the author will confine himself strictly to the correction of idiopathic scoliosis in children. The equally difficult problem of maintaining the correction does not enter into the province of the present paper.

THE IMPORTANCE OF THE ROTATIONAL ELEMENT IN THE DEFORMITY

The deformity is complex, consisting of a lateral deviation of the spine with rotation of the vertebrae. Opinion is still divided on the questions of whether the lateral deviation or the rotation is the initial deformity, and whether these two changes may be independent of each other or the natural concomitants of some underlying cause. However, it is generally assumed that rotation is secondary to lateral deviation. The latter element is always accompanied by some rotation except in the very mildest grades; while in the more severe curvatures, rotation is pronounced. Moreover, in some instances, notably the so-called "razor backs", rotation is the main element in the deformity.

No constant ratio exists between these two components, but the rotational defect is the more resistant to correction. In fact, it is doubtful whether derotation can be effected in any but the mildest curvatures, and this fact is borne out in the results in the cases to be described.

Resistance to correction is due mainly to structural changes in the vertebrae,—changes indicated by the appearance of wedging of the vertebral bodies, as seen in the anteroposterior roentgenograms (Fig. 1). On purely mechanical grounds, this wedging may explain the resistance to correction of the lateral deviation, but it does not explain the

* Based on a paper read at the Annual Meeting of The British Orthopaedic Association, Oxford, England, January 3, 1941.

2. In the other two (Figs. 18-A, 18-B, 19-A, and 19-B) it was clear that the severity of the curvature would not allow full correction.

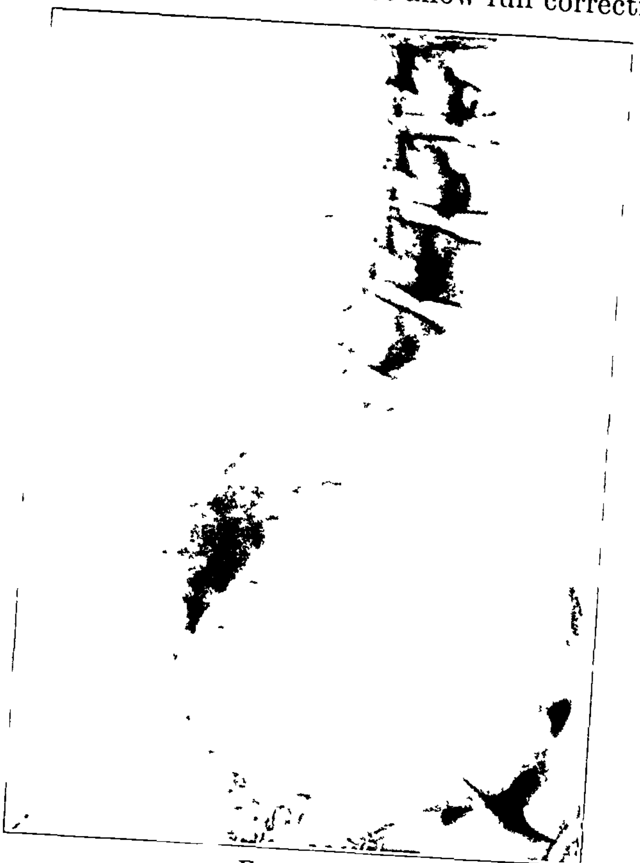


FIG. 17-A

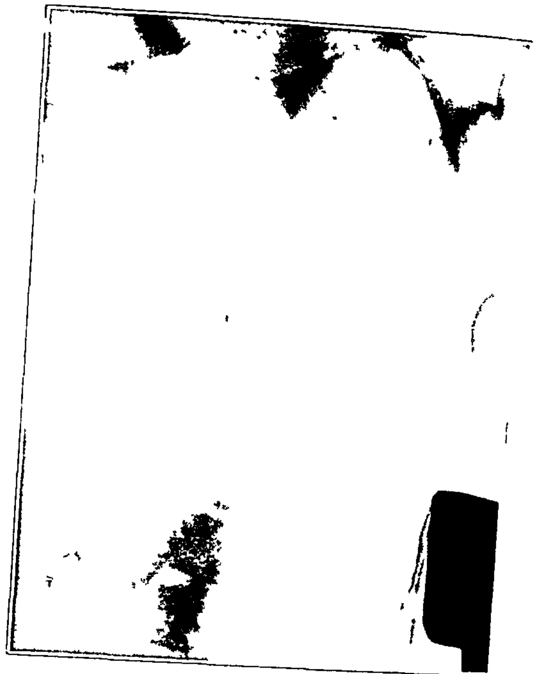


FIG. 17-B

Case 13. B. G., a girl, aged fourteen. This case was unsuitable for method, because the curve is too high and counterpressure is not practicable.

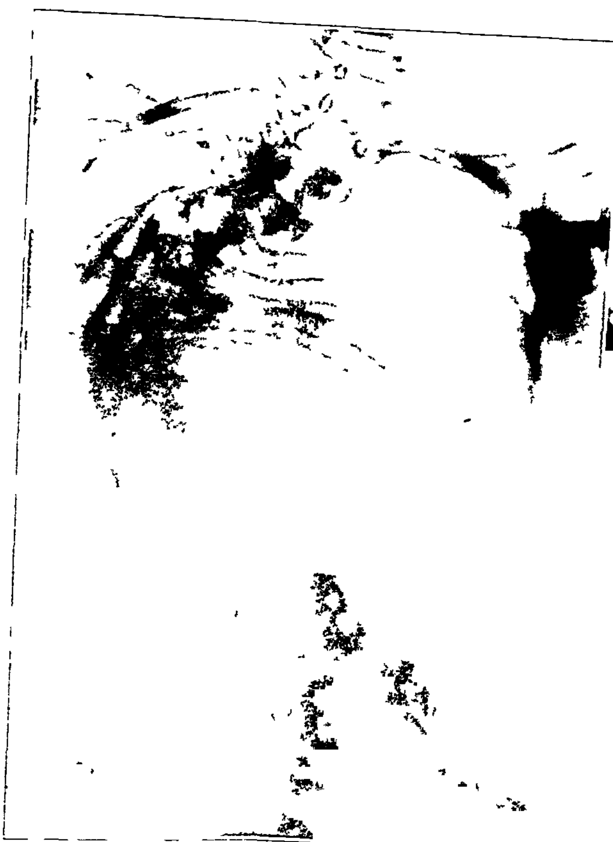


FIG. 18-A

FIG. 18-B

Fig. 18-A: Case 14. E. M., a girl, aged fourteen. An extreme type of deformity with severe structural changes.
Fig. 18-B: In spite of this, an appreciable amount of correction has been obtained.

FIG. 5-A FIG. 5-B

Fig. 5-A: Case 1. E. M. B., a girl, aged twelve. Moderate wedging and rotation.
Fig. 5-B: After correction, wedging is more obvious and derotation has occurred.

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 2. M. N., a girl, aged fourteen. Mild degree of wedging, but severe rotation.
Fig. 6-B: Roentgenogram, taken after corrective forces have been removed, shows improvement of lateral *deviation, but only slight improvement of rotation.*

OSTEOID OSTEOMA

Review of the Literature and Report of Thirty Cases *

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Although instances of osteoid osteoma had been reported under other names before Jaffe's original paper, the lesion had not been generally recognized.

Probably the first description of the pathological picture of this disorder was made by Bergstrand, who, in 1930, reported two cases,—one in a metatarsal, and one in the phalanx of a finger. Clinically, both were thought to be osteogenic sarcoma. The metatarsal was resected, and the finger was amputated. The detailed clinical data and the excellent photomicrographs leave no doubt as to the identity of the lesions. Bergstrand interpreted them as rare benign osteoblastic lesions and, because he thought them neither neoplastic nor inflammatory in nature, he attributed them to embryonal rests.

In 1934, Milch described this lesion and recognized the similarity of his cases to those of Bergstrand. He concluded that he was dealing with a benign osteoblastic tumor, forming osteoid tissue, and recommended surgical excision.

The lesion received little attention, however, until 1935, when Jaffe published an account of Milch's three cases and also of two more, with a careful analysis of their individual clinical and pathological characteristics. To Jaffe is due the credit for establishing this lesion as a distinct entity. Marziani's paper, in 1936, presented one more case. Rinonapoli added three cases in a report in 1937. In 1938, seven cases were reported by Mondolfo, who interpreted them as chronic osteomyelitis. By 1940, Jaffe and Lichtenstein had added twenty-eight more cases. Since then reports of many cases have been published [1, 2, 6, 7, 8, 9, 11, 12, 13, 14, 18, 22, 23, 24, 27, 29, 30, 32, 34, 35, 36, 37, 39, 40]. The last comprehensive report was made by Jaffe in 1945, when he presented his total of sixty-two cases and gave a general review of the subject, including a restatement of the argument as to whether or not the osteoid osteoma is a separate lesion.

As one would expect, in the older literature, reports of osteoid osteomata are presented as examples of other lesions. In 1929, Phemister described under the term "chronic fibrous osteomyelitis" several cases, among which can be distinguished one that is unquestionably an osteoid osteoma. Two more instances of this lesion were reported by Compere, in 1932, as *Streptococcus viridans* osteomyelitis. All three of these cases are included in the present series. In 1935, Zanoli described a case which he considered to represent an incomplete repair of a post-traumatic aseptic necrosis. From the excellent illustrations, it is easily identified as an osteoid osteoma of the capitate.

In addition, there are several reports, such as those of Heine, Hitzrot, Raspall and Llort, Thoma, and Weeden and Oliva, which are suggestive of osteoid osteoma, but which do not include sufficient data to permit definite diagnoses.

CLINICAL PICTURE

The clinical features of osteoid osteoma are by now well known. The disorder is much more common in the male. Of 127 cases in which the sex was reported, eighty-seven were males; of the thirty additional patients here reported, twenty are males. Thus, the ratio of males to females is greater than two to one. Only one case has been reported in a negro.

It has been said by Jaffe that the lesion has a predilection for adolescents and young

* This work was aided by a grant from the Douglas Smith Foundation.

the shadows on the convex side of the deformity will be displaced medially away from the lateral borders of the bodies on that side (Fig. 1, *A*), while those on the concave side will

FIG. 9-A

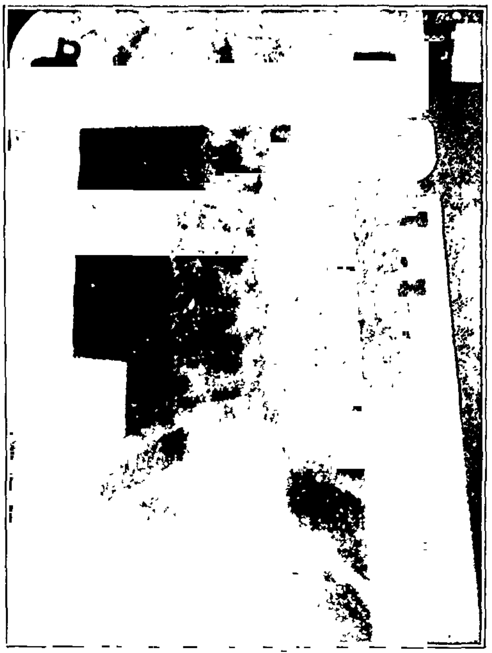


FIG. 9-B

Fig. 9-A: Case 5. N. R., a girl, aged ten. Moderate wedging and severe rotation.

Fig. 9-B: Lateral deviation is much improved, but rotation remains the same.

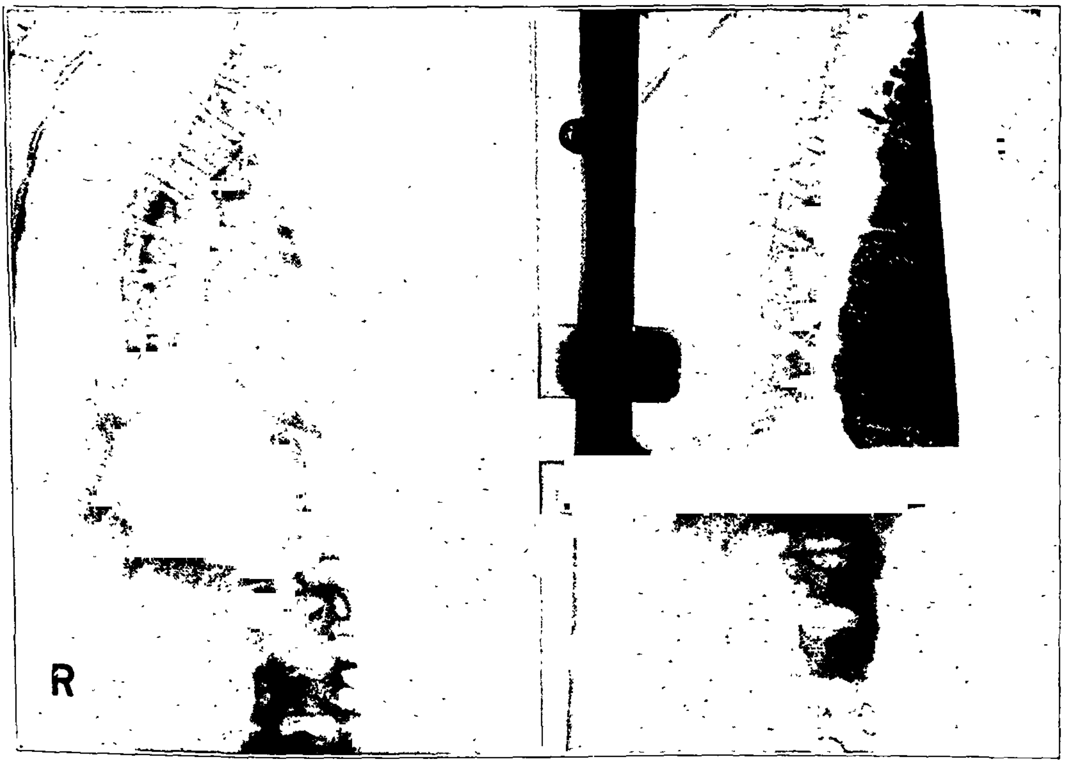


FIG. 10-A FIG. 10-B

Fig. 10-A: Case 6. H. S., a girl, aged thirteen. Severe wedging and rotation.
Fig. 10-B: Rotation unaffected, although lateral deviation has improved.

TABLE II

LOCATION OF LESION

Bone	Cases in the Literature	Present Series	Total
Tibia	33	4	37
Femur	24	7	31
Astragalus	12	1	13
Vertebrae	11	7	18
Humerus	9	1	10
Fibula	7		7
Toes	6	3	9
Fingers	5	4	9
Os calcis	4		4
Radius	3	1	4
Ulna	3		3
Carpal navicular	3		3
Ilium	2	1	3
Patella	1		1
Pubis		1	1
Tarsal navicular	1		1
Hamate	1		1
Capitate	1		1
Ankle	1		1
Rib	1		1
Totals	128	30	158

present series correspond well with those given in the literature. The only noteworthy exception is that almost 25 per cent of the lesions of our series were lesions of the spine which were as numerous as those in any other category,—probably because of our group's special interest in this particular disorder. A separate paper on these cases is being published elsewhere [15]. In any given bone, the lesion may be entirely in cancellous bone beneath or in the cortex, or even in subperiosteal tissue.

All the patients in this series sought medical advice because of pain. Their stories are remarkably similar. The pain, which at first was rather vague, mild, and intermittent gradually grew in severity and constancy and localized to a very small area Twenty-four of the thirty patients volunteered the information that the pain was most severe at night and often prevented sleep or awakened them. Three patients had had symptoms for only two months; twenty-one for from six months to two years; and the remaining six, for more than two years. One patient had had unremitting pain for six years. When the lesion is in the spine, there may be associated root pain and even symptoms of cord compression [15, 25, 28, 34].

The chief physical finding is that of tenderness, which usually can be definitely localized, even by the very young patient, and which may be exquisite. If the lesion has been present long enough, there is usually palpable thickening of the bone. Lesions in bones with little soft-tissue covering may be accompanied by swelling, but this area is rarely warm and never red. If the site of the lesion is near a joint, motion of that joint is often limited and painful. Occasionally there is increased fluid in the joint, and the findings may be such as to simulate a primary arthritis [36]. Involvement of the lower extremity usually produces a limp and atrophy of the muscles. In the spine, an osteoid osteoma produces all the signs of acute localized back pain, including muscle spasm, secondary scoliosis, and pelvic tilt.

There are no systemic complaints or findings. The patients are afebrile and have normal blood counts.

FIG. 13-A

Fig. 13-A: Case 9. J. K., a girl, aged six. Even at this early age it was not possible to achieve full correction.

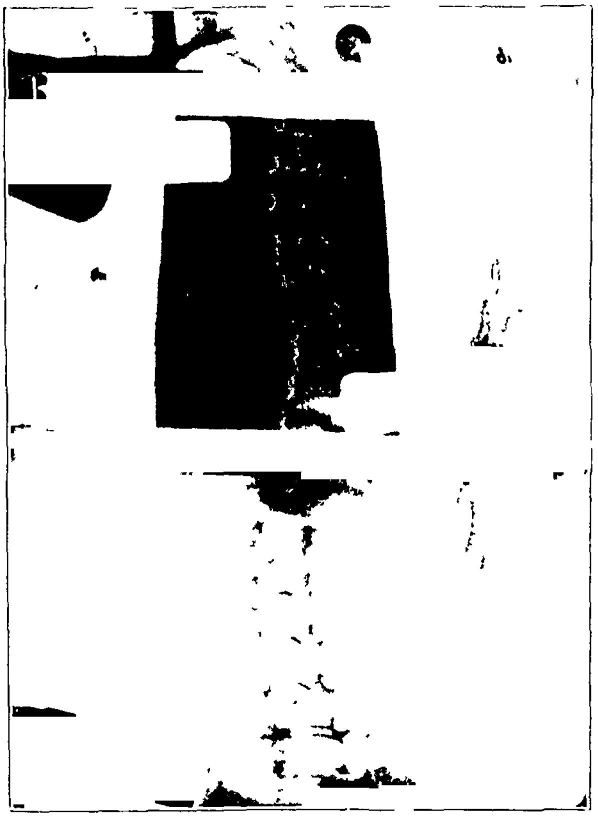


FIG. 13-B

Fig. 13-B: The lateral deviation is improved, but rotation, which was severe, is only slightly reduced.

one another, it will be seen that the articular facets on the concave side are thrown out of alignment with those on the convex side, with consequent locking of the vertebrae in their rotated position.

While realizing that contracture of soft parts is a factor preventing correction, the writer believes that the most formidable obstacle consists in these complex twists of the arch. These changes are not fully revealed roentgenographically, and we have no means of measuring their extent, but wedging of the centra is to be regarded as an indication of their presence.

On examination of the patient, rotation is generally less apparent than lateral deviation, and fortunately the latter component can be reduced greatly by treatment.

METHOD OF CORRECTION

The method to be described consists in a combination of recumbency, traction, and lateral pressure.

1. *Recumbency:* Since the upright posture favors the progress of the deformity, recumbency is an important factor in its correction. The influence of gravitation is eliminated by placing the patient on a Thomas spinal frame, fitted with a head piece.

2. *Traction in the Axis of the Spine:* Although the usefulness of intermittent traction during the application of plaster jackets in suspension has long been recognized, the value of continuous traction in the treatment of scoliosis has been underestimated. Indeed Lovett [1] believed that, when traction is exerted on the spine, the tension so produced prevents lateral pressure from exerting any corrective influence. The cases to be described do not support this belief. Longitudinal traction is exerted on the spine by fixing the lower extremities by extension strapping to the foot pieces of the frame, and by applying weight traction to the head through a Sayre halter.

3. *Lateral Pressure:* In order to exert lateral pressure, special appliances have been devised, and with the employment of these the amount, direction, and site of the thrust

Sections of the material removed at operation showed a very immature lesion (*Fig. 2-B*). The fibrous-tissue stroma was extremely cellular, and there were great numbers of multinucleated giant The osteoid tissue was prominent; but, instead of being deposited in irregular masses, it was arran

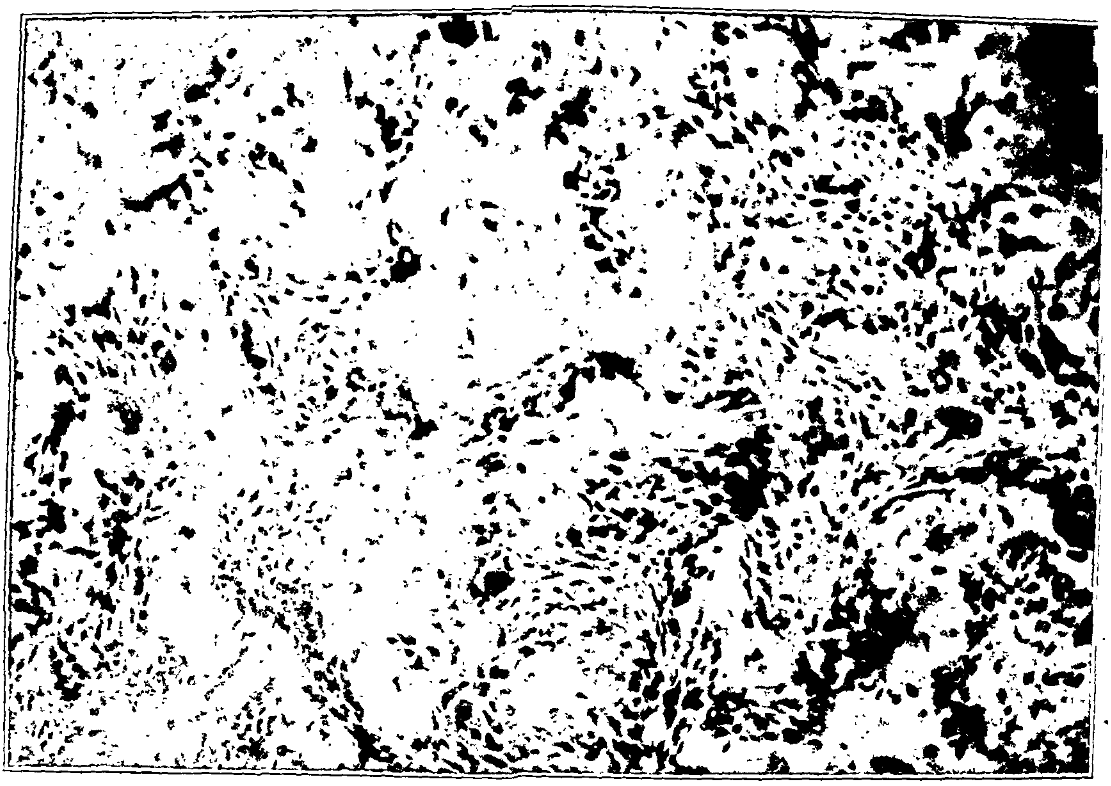


Fig. 2-B

Photomicrograph (× 200). At the center of the lesion there is cellular fibrous tissue, containing giant cells and many well-formed irregular trabeculae of osteoid tissue.

Fig. 2-C

Photomicrograph (× 200). Nearer the periphery, there is calcification of some of the trabeculae.

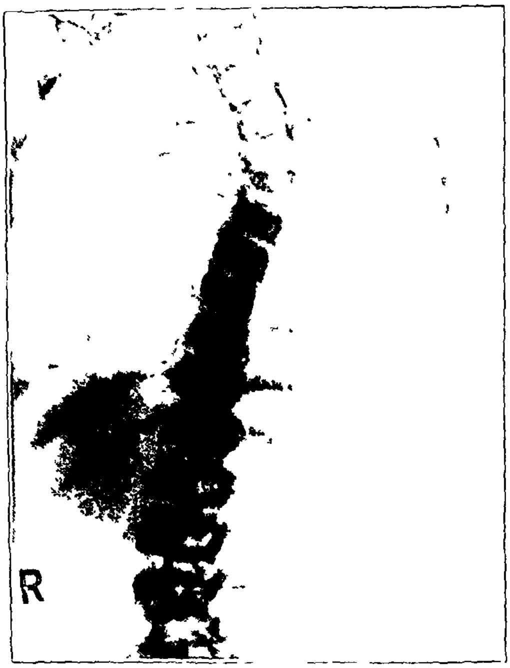


Fig. 15-A

Fig. 15-A: Case 11. P. N., a boy, aged six. A fairly acute curve in the upper thoracic region, with severe wedging of the fifth thoracic vertebra.

Fig. 15-B: Good correction of lateral deviation, but rotation is still present.

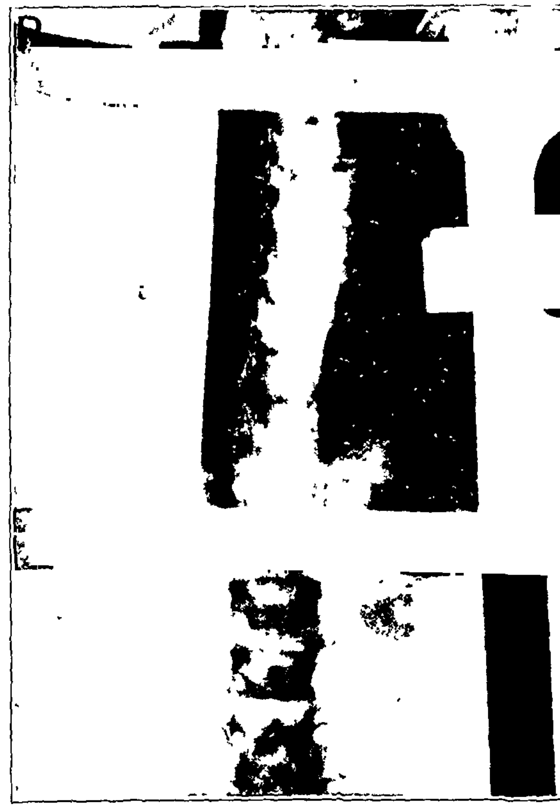
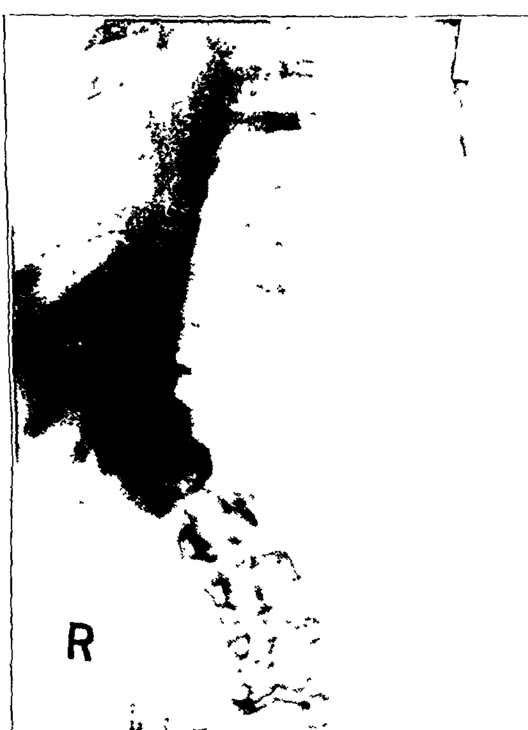


Fig. 15-B



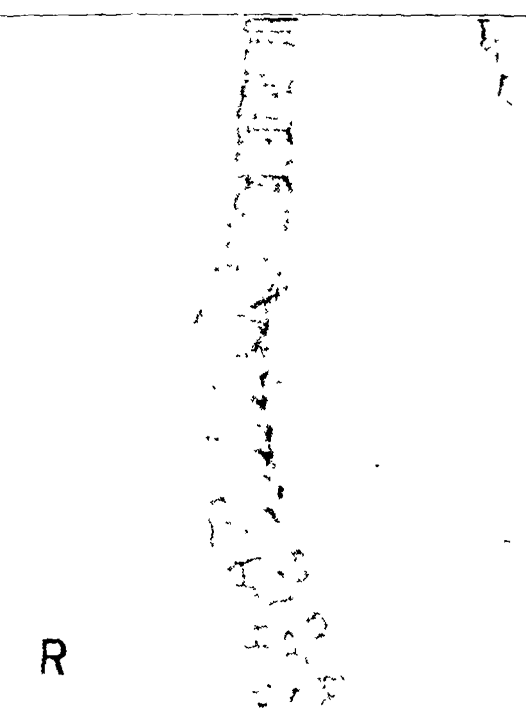


Fig. 16-A

Fig. 16-B

Fig. 16-A: Case 12. J. C., a girl, aged eight. A sharp thoracolumbar curve with severe rotation.

Fig. 16-B: Roentgenogram, taken without corrective forces acting, shows good correction, but rotation is still severe.

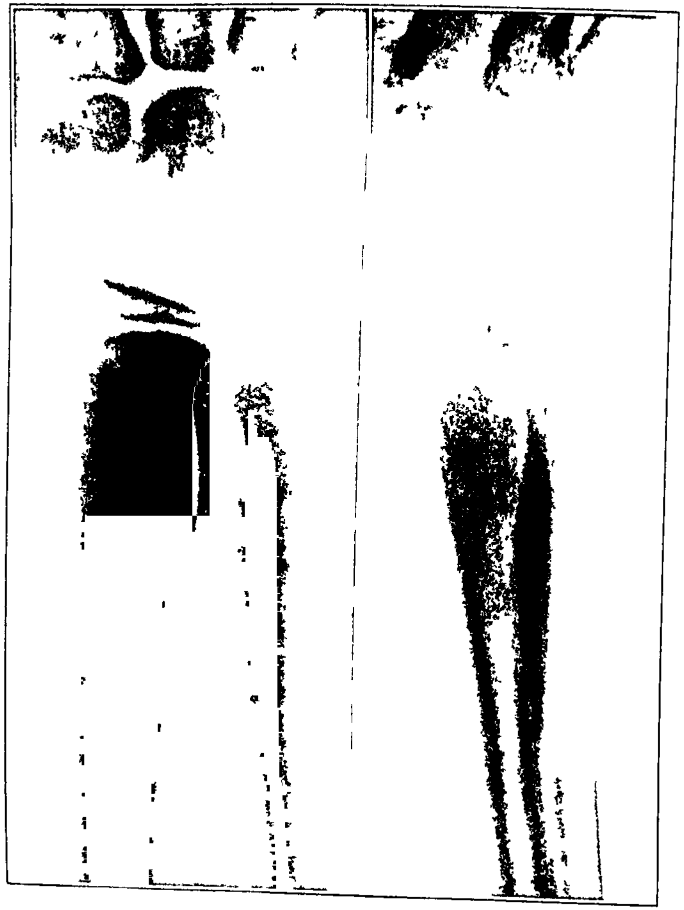


Fig. 1-A

Case 3. Roentgenograms show a radiolucent lesion in the distal portion of the radius, surrounded by marked sclerosis. There is the shadow of periosteal new bone on both radius and ulna. (Illustrations have been reversed.)

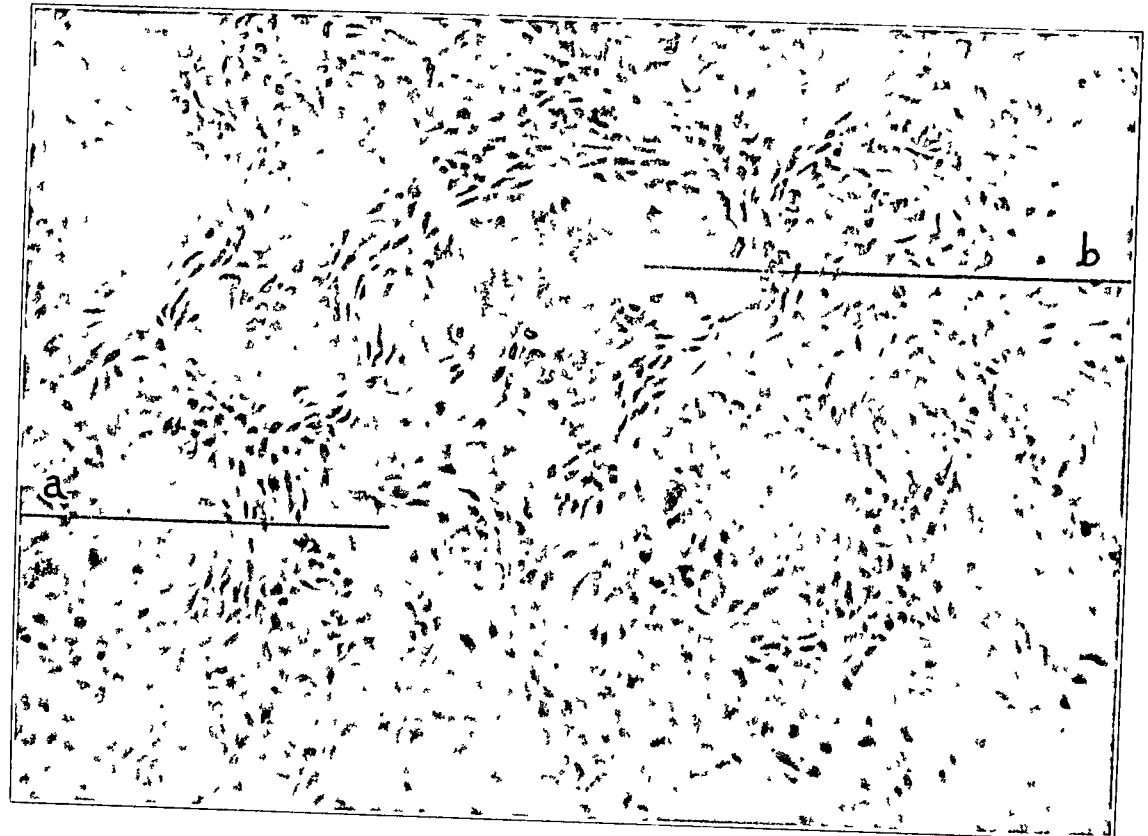


Fig. 4-B

Photomicrograph (× 300) shows immature lesion with little organization. In the fibrous stroma are small irregular trabeculae of osteoid tissue (*a*), and a few where calcification has just begun (*b*).

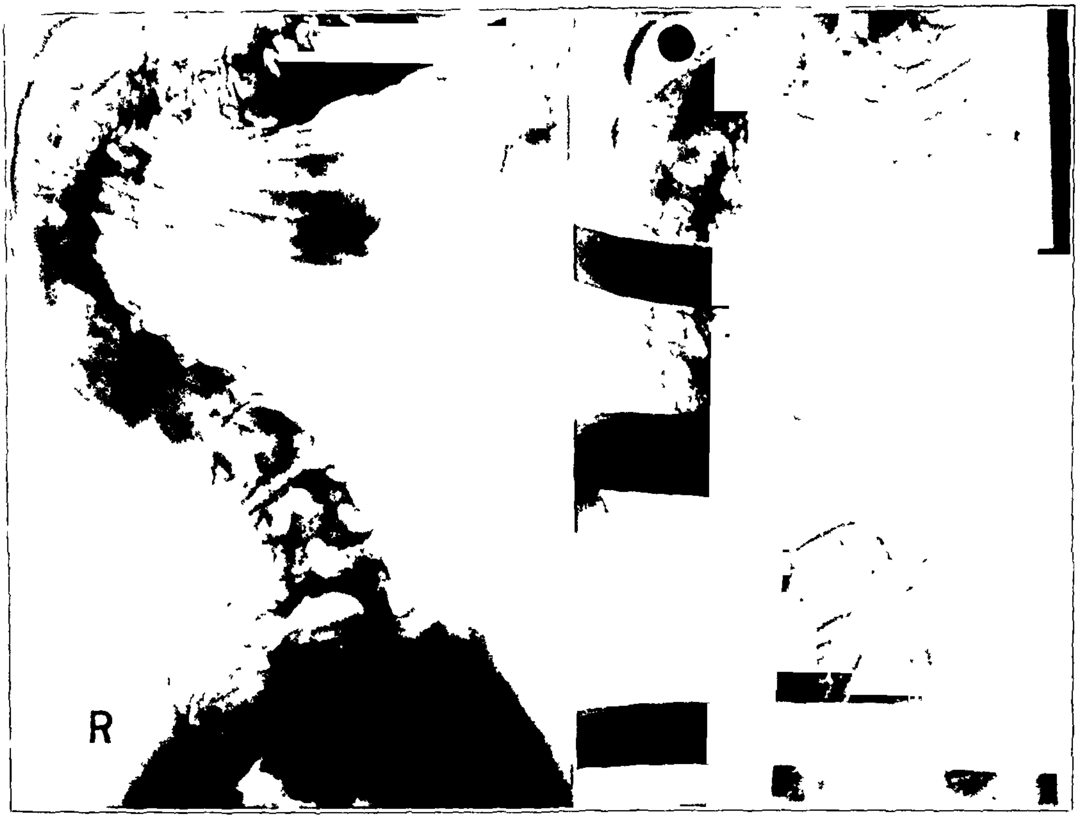


FIG. 19-A FIG. 19-B

Fig. 19-A: Case 15. M. C., a girl, aged thirteen. This case was unsuitable for method, because curve is too severe.

Fig. 19-B: Slight amount of correction has been obtained.

It is also obvious that a lumbar curve is not amenable to this form of treatment, because of the absence of any structures through which pressure can be applied effectively.

Progress: It was interesting to observe that in every case the maximum correction obtainable was secured within eight weeks, and that no matter how much the forces were increased, or how long they were in operation after this period, no further improvement could be obtained.

Complications: In the fifteen patients treated, there were complications of a minor character in but two. In one a sore developed under a pressure pad, and healing ensued after complete release of pressure for three weeks. Following this, pressure was re-applied more gradually. In the other patient, a slight palsy of one arm was relieved by release of the pressure, which was later re-applied at a slightly lower level. There were no complications due to traction by the Sayre halter.

SUMMARY

The results from this method of correction of idiopathic scoliosis show very encouraging improvement over those obtained by other methods.

From the study of these patients, the writer has not been able to draw any conclusions as to why some cases of curvature are more amenable to correction than others of the same apparent severity, at the same age.

Rotation was a prominent feature in all, but the amount of lateral correction obtained did not appear to bear any constant relationship to it. This rotation was corrected in only two cases (Figs. 5-B and 8-B); in all the others, it persisted or even increased.

1. Lovett, R. W.: Lateral Curvature of the Spine and Round Shoulders. Philadelphia, P. Blakiston's Son and Co., 1907.

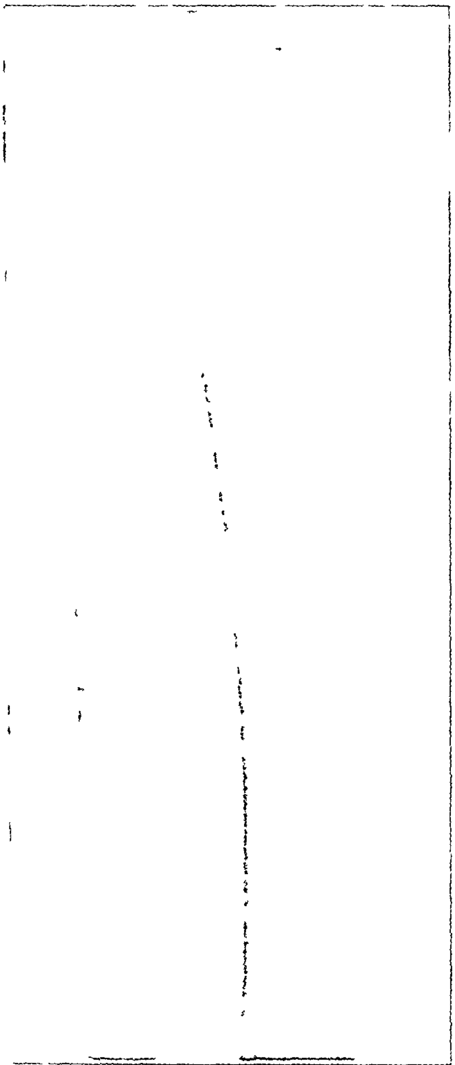


FIG. 6-A

FIG. 6-B

FIG. 6-A. Case 5. Roentgenogram shows radiolucent center in anterior part of proximal portion of the tibia. It is surrounded by dense sclerosis, and there is considerable thickening of the cortex. (Roentgenogram has been reversed.)

FIG. 6-B. In this photomicrograph (X 12) there are three separate well-developed centers. Some hypertrophic regional bone is visible, but most of the peripheral material is dust, produced by the use of a motor drill.

CASE 3. R. H., an eight-year-old boy, presented himself in November 1944, because of pain in the left wrist. This pain was said to have begun two months before, immediately following a six-foot fall in which the patient landed on outstretched hands. The pain was acute and was localized over the lower portion of the radius. It was always worse at night, and kept the boy from sleeping.

Physical examination disclosed no abnormalities except in the left wrist, which was markedly swollen and warm to the touch. There was exquisite point tenderness over the distal portion of the radius, and so much pain on motion that the patient carried his left forearm cradled in his right. Routine laboratory procedures, including a skin tuberculin test, yielded normal results.

Roentgenograms revealed marked sclerosis with subperiosteal new-bone formation on the lateral aspect of the radius, just above the distal epiphysis (Fig. 4-A). In the center of this mass was an oval area of decreased density. There was also the shadow of periosteal new bone on the adjacent ulna.

At operation, the affected region was readily identified by the gross thickening, but the center could not be seen. Therefore, the entire sclerotic area was excised. The wound healed by first intention, and there was immediate relief of symptoms. The swelling decreased slowly, but was still in evidence one year later, when the patient was asymptomatic.

No nidus could be found grossly among the pieces removed at operation, but the characteristic tissue appeared on the sections (Fig. 4-B). The usual background of cellular fibrous tissue was present, and there were a small number of giant cells. In this tissue were fragmentary irregular trabeculae which were composed mostly of osteoid tissue. Here and there were wisps of bone in the centers of the trabeculae.

CASE 4. C. T., an eight-year-old girl, was seen in March 1940, complaining of pain in the medial por-

TABLE I

AGE INCIDENCE

Age (Years)	Reported Cases	Present Series	Total
1–5	8	1	9
6–10	9	9	18
11–15	30	8	38
16–20	35	5	40
21–25	24	2	26
26–30	14	2	16
31–35	3	2	5
Over 35	2	1	3
Not stated	3		3
Totals	128	30	158

adults. Indeed, over half of the patients already reported are between ten and twenty years old. As may be seen in Table I, the age incidence in the present series is slightly different, with over half of the patients between the ages of five and fifteen years. The youngest patient in our series was three years old and the eldest was fifty-one.

In Table II, the locations of the previously reported lesions are compared with those of the present series. It will be seen that, in general, the locations of the lesions in the

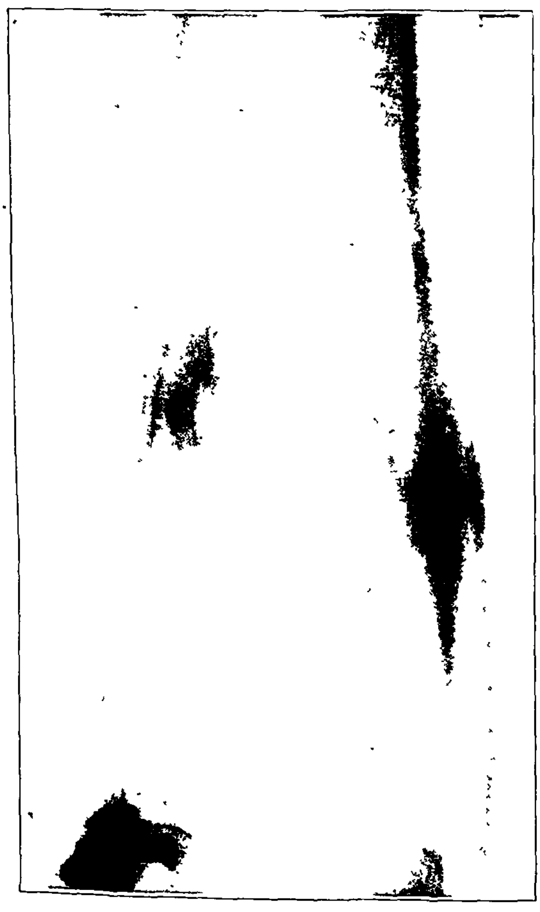


FIG. 1-A

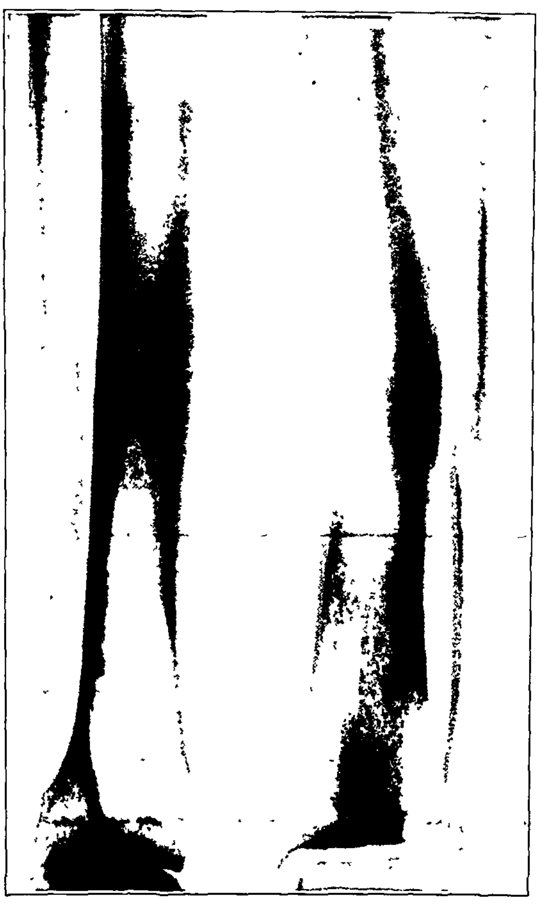


FIG. 1-B

Fig. 1-A: Initial roentgenograms of the left tibia, showing a densely sclerotic area with an oval radiolucent center.

Fig. 1-B: Roentgenograms twenty-four years later, showing persistence of sclerosis, but no demonstrable nidus.

Sections showed a picture that was characteristic, but slightly unusual (Fig. 6-B). In one end of the block, there were three distinct rounded centers, separated from each other by fibrous tissue and normal bone. Each focus had a central portion, composed of vascular fibrous tissue with many giant cells (Fig. 6-C), and surrounded by a wide ring of masses of osteoid tissue. Here and there within the osteoid tissue were tiny fragments of irregular new bone. At the periphery, regional hypertrophic bone with moderately fibrous marrow was present, and beyond this was completely normal bone.

DISCUSSION

The etiology of these lesions is still unsettled and is the subject of much debate. Most authors who have studied actual examples of osteoid osteoma are in agreement with Jaffe that it is a distinct entity. There exists, however, no such agreement as to whether or not the lesion is a benign neoplasm, as Jaffe contends.

Previous trauma is frequently mentioned as a possible predisposing factor, as it is with almost any skeletal lesion. Among our thirty patients were three with a history of severe trauma to the hand or wrist, who stated that symptoms had begun immediately and had not subsided until operation. Of these patients, two had lesions in the phalanges of the fingers and one in the distal portion of the radius. Five other patients gave a vague history of injury at varying time intervals preceding the onset of trouble. Twenty-one patients stated specifically that there had been no trauma. In view of the known propensity of patients to relate all skeletal disorders to some type of injury, and in view of the small number of such histories related to osteoid osteomata, it seems safe to disregard trauma as of etiological significance.

The only authors who have denied categorically the existence of osteoid osteoma are Brown and Ghormley. They reported a series of twenty-four cases which they considered to be examples of the condition described by Jaffe. Fourteen of their patients were operated upon, and pathological examination of the material removed from ten patients showed "chronic inflammatory tissue". The photomicrographs presented certainly substantiate this diagnosis, and do not resemble the picture of an osteoid osteoma. In two cases, *Staphylococcus aureus* was cultured, and in two, a micrococcus. Quite correctly the authors considered these to be cases of bone abscess. Their reasons for maintaining that osteoid osteomata are all identical solitary chronic bone abscesses are, however, not very clear.

In a paper published in 1942, Brailsford presented several cases with roentgenograms which are compatible with diagnoses of osteoid osteoma. From three of the patients who underwent surgery, *Staphylococcus albus* was cultured. Because of this and the roentgenograms, Brailsford called these lesions chronic subperiosteal abscesses. He then made a general statement that the pathological changes were like those described by Jaffe; however, there are not enough data in Brailsford's paper to establish the similarity. Because of the findings in these cases, Brailsford assumed that all osteoid osteomata are a distinctive variation of an infectious process.

Actually, the weight of evidence is clearly against infection as the etiological agent in osteoid osteoma. The patients never have fever, leukocytosis, or other systemic manifestations. When swelling is present, it is only occasionally warm, and there is no redness. The lesions are always solitary and never recur after complete excision; and after operation the wounds invariably heal by first intention. The few positive cultures which have been reported have usually been of *Staphylococcus albus* or some other common contaminant. In our own series, cultures were made in twenty-two instances. Of these, nineteen produced no growth. One each produced *Streptococcus viridans*, *Staphylococcus albus*, and diphtheroids, all of which are considered to be contaminants. In five cases, guinea pigs were inoculated, and none of these showed evidence of disease. In six additional cases, skin tuberculin tests were negative. Twenty-four of the patients had negative Wassermann or Kahn reactions. It is clear that the history, physical findings, and course of these patients are not consistent with an infectious process.

Roentgenographic examination of a mature lesion reveals a characteristic picture. The active nidus is usually a small round or oval area of reduced density. Often one can see within it a small dense shadow, which represents ossification of the central portion. About this nidus, a thick, dense shadow of sclerotic regional bone is almost always present. If the lesion is at or in the cortex, the regional hypertrophy, especially along the periosteal surface, is much greater. The circumference of the shaft may be so greatly increased, and the bone may be so sclerotic, that the nidus is difficult to demonstrate by roentgenogram.

The response to the treatment of osteoid osteoma is most satisfactory, for immediate and permanent relief of symptoms follows excision of the nidus. It is not necessary to remove all of the hypertrophic regional bone, which may gradually resorb, particularly in children; but, if the nidus is not excised completely, persistence or recurrence of symptoms is the rule.

Since only eight of 155 patients were older than thirty, one is justified in assuming that the lesion may heal spontaneously.

In this connection, the history of a man who is not included in this series is of interest. In 1916, when he was eighteen years old, he consulted Dr. D. B. Phemister because of pain, tenderness, and swelling, which had been present in the lower portion of the left tibia for one and one-half years. Roentgenograms (Fig. 1-A) showed a lesion which we would now have no hesitancy in calling an osteoid osteoma. Surgery was refused by the patient. Gradually the pain and tenderness decreased; and, by 1921, seven years after their onset, the symptoms had disappeared and did not return. In 1940, twenty-four years after his initial visit, the patient was examined again. Swelling was still present, but there was neither pain nor tenderness. Roentgenograms (Fig. 1-B) showed persistent sclerosis and thickening of the cortex, but there was no sign of the nidus. A similarly suggestive case is included in the report made by Moberg.

Fig. 2-A

Case 1. Initial roentgenogram, showing a large radiolucent lesion at the juncture of pubis and ischium. As yet, very little reaction of surrounding bone is evident.

Most of the general characteristics are illustrated in the following typical case reports.

Case 1. E. G., a sixteen-year-old girl, was first seen in March 1944, complaining of pain in her right leg, which had begun one year before. At first mild, generalized, and intermittent, the pain had gradually become more severe and had centered in the knee and thigh. For two weeks before her admission, she had been unable to walk and the pain had kept her awake at night. There was a vague history of a bruise on the right hip a month before symptoms began. There had been no fever or infectious diseases.

Physical examination was normal except for pain in the hip with extremes of abduction and adduction, and tenderness over the pubis, which could be elicited by rectal examination. The results of routine laboratory examinations were all within normal limits.

Roentgenograms of the pelvis showed a radiolucent lesion at the juncture of the right pubis and ischium (Fig. 2-A). There was relatively little sclerosis of the regional bone. The preoperative diagnosis was enchondroma.

At operation, a bulging mass of hemorrhagic fibrous tissue, about 2.5 centimeters long, was removed; and its bed was curetted. There was primary healing of the wound, and tissue cultures showed no growth.

The patient was immediately relieved of pain, and returned to normal activity as soon as the wound had healed. When last seen, four months later, she was still asymptomatic.

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delicate, well-formed, interlacing trabeculae. Most of these showed no cation at all, but in a few places the trabeculae had become bone (Fig. 2-C).

While this lesion was unquestionably an osteoid osteoma, it showed much more of a pattern than is usually the case.

CASE 2. J. D., a sixteen-year-old male, was seen in June 1940, complaining of pain in his right knee, which had begun six months before, without any preceding illness or trauma. The pain was severe, constant, and prevented sleep.

Physical examination revealed a fusiform enlargement of the right femoral shaft and localized tenderness on the medial side, just above the mid-shaft. Laboratory examinations gave no unusual findings.

A roentgenogram showed a large fusiform mass of sclerotic new bone on the medial side of the femoral shaft, extending from the lesser trochanter along the cortex to the distal third of the femur (Fig. 3-A). Beneath the mid-point of this mass was a small area of lesser density. This area was found at operation to be a definite cavity, filled with brownish granulations. The cavity was thoroughly cleaned out, but no attempt was made to remove all the surrounding hypertrophic bone. Cultures made in the operating room produced no growth, and the wound healed by first intention.

After the operation, there was immediate and complete relief of pain. When the patient was last seen, four years later, he was still asymptomatic. A roentgenogram showed that the remaining hypertrophic new bone was unchanged.

Sections of the material curetted from the cavity showed the center of the nidus (Fig. 3-B). The fibrous-tissue background had unusually large blood spaces and relatively few giant cells. Ossification was fairly well advanced, with numerous heavy trabeculae present in an irregular pattern. Little osteoid tissue was seen in this portion; but in the zone immediately surrounding it, osteoid tissue was present in amorphous masses.

FIG. 3-A

Case 2. Roentgenogram of femur shows dense mass of hypertrophic bone on medial aspect of shaft. Beneath the center of the mass is a small radiolucent area.

FIG. 3-B

Photomicrograph (× 96) shows vascular fibrous stroma with giant cells. The center of this lesion is almost all irregular bone (*a*). Surrounding it is a zone of amorphous deposits of osteoid tissue (*b*).

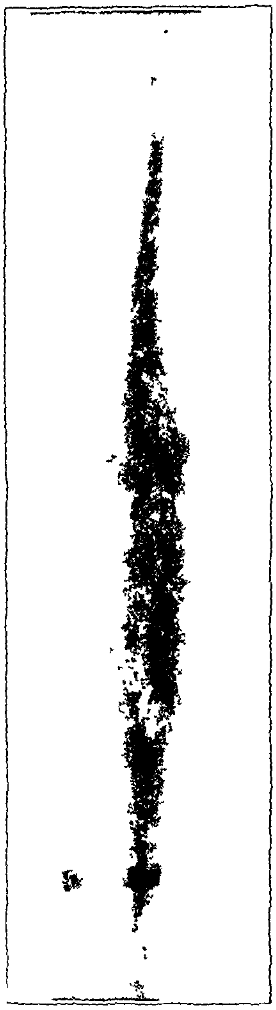

FIG. 3-A

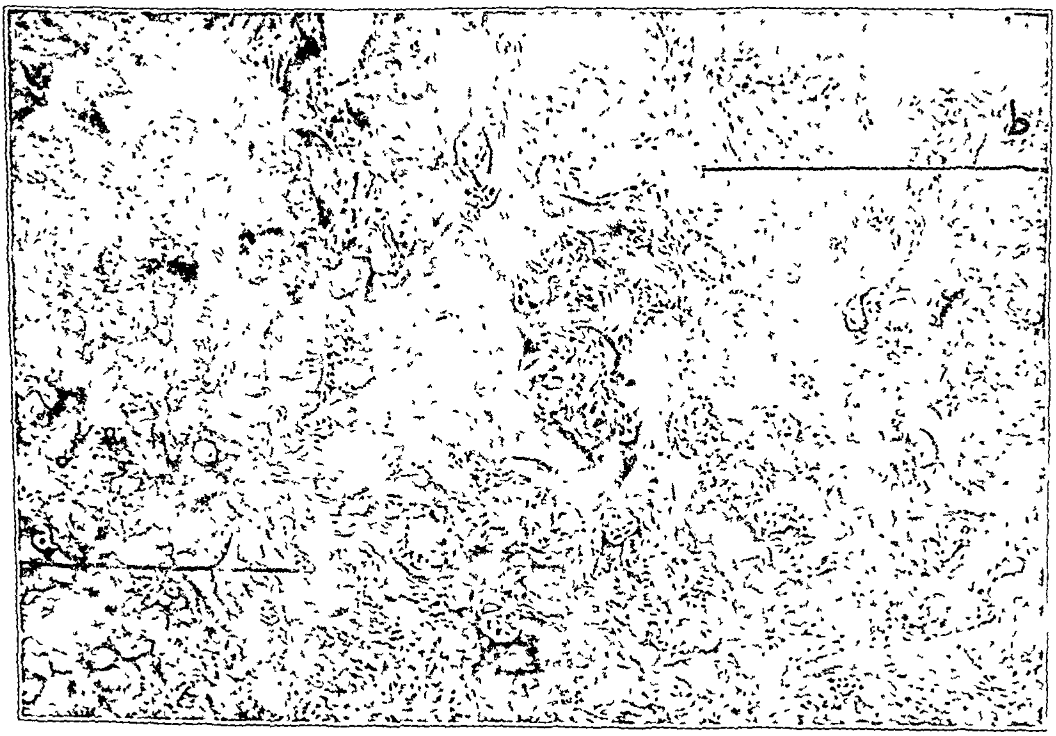

Fig. 3-B

resection of the degenerated cartilage as a means of preventing the development of degenerative arthritis. This suggestion has not been widely accepted. Erb, in 1933, reported a ten-year follow-up of eighteen patients operated upon. He found that, although subjective improvement was noted in all patients, the operation did not retard the further development of degenerative arthritis. These results have been verified by other observers [21].

The present theory is that degeneration of the patellar cartilage can exist with or without trauma. A large number of pathological investigations have shown that degenerative changes are frequently found in the knee; these changes increase with age. Heine, in 1926, reported his observations in the examination of 1,002 cadavera of patients who died between the ages of fifteen and ninety-five. He found that the greatest number of degenerative changes occurred in the knee joint. These changes occurred first in the patella and subsequently reached their greatest development in this bone. In 49 per cent. of these cases, the same degree of change was evident in both knees; in 35 per cent., the condition was worse in the right knee; and in 16 per cent., the left knee showed the greater damage. No sex difference was noted.

Of forty-four cadavera, Läwen found changes in the knees of twenty-six. These changes were most pronounced on the cartilage surface of the patella, and in most of the cases both patellae were involved. Silfverskiöld found that, in 170 autopsies, 24 per cent. of the individuals between fifteen and twenty years of age had a mild degree of degeneration of the patella.

Øwre investigated 124 cadavera with presumably healthy knee joints. Although there had been no complaints referable to the knee, he found degeneration of the patella as follows:

1 to 19 years of age, 5 cases out of 18 (all over 14 years old)
20 to 29 years of age, 27 cases out of 32
30 to 39 years of age, 24 cases out of 26
40 to 59 years of age, 30 cases out of 32
60 to 80 years of age, all 16 cases

The degree of severity of involvement increased with age.

In 1942, Bennett, Waine, and Bauer reported their study. The purpose of their investigations was to familiarize themselves with the so-called normal knee joint at each decade of life. They found that all joints obtained from individuals beyond the second decade of life exhibited alterations similar to those observed in degenerative arthritis; and the degree of degeneration in the individual specimen was not proportional to the degree of arteriosclerosis found in the peripheral vessels. They concluded that articular cartilage remains normal for only a short time following complete maturation.

Heine, Keefer and his associates, and Silfverskiöld found no relationship between the extent of degeneration and the occupation of the individual.

In the clinical investigation of 640 patients, Hinricsson found that the frequency of occurrence in different age groups was about the same as that reported by various other investigators.

Freund, in 1939, emphasized the belief that, under normal conditions, joint cartilage requires friction and pressure to remain healthy; any variation of these stimuli, either above or below the physiological optimum, if active over a long period, would be deleterious to the joint cartilage. This had been previously shown by Müller and Benninghoff (1924) in animal experiments.

In 1944, Hirsch, after an intensive study of patellae removed at autopsy and at operation, reported his observations on the physical, histological, and chemical investigations in chondromalacia of the patella. He found that normal cartilage could adapt itself functionally to an increased pressure with almost complete recovery of its elasticity, provided the pressure per unit area did not exceed the tensile strength of the cartilage and was maintained for a short duration. However, if the pressure did not exceed the tensile

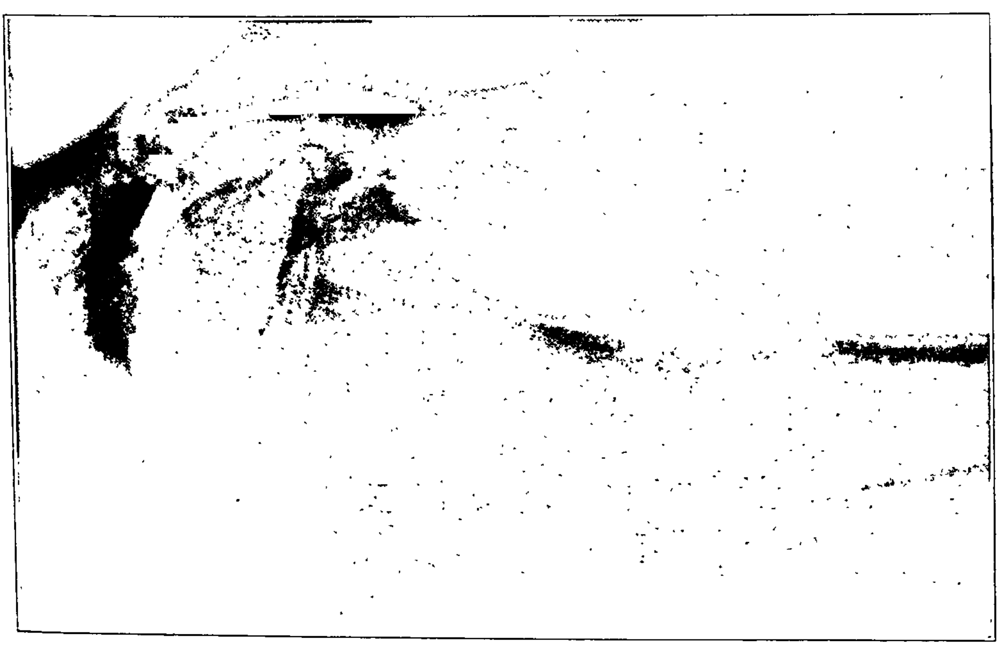

Fig. 5-A

Fig. 5-B

Fig. 5-A: Case 4. Roentgenogram shows a round lesion with a dense center in the greater trochanter. There is a sclerotic ring about the periphery, but minimum reaction of the surrounding bone. (Illustration has been reversed.)

Fig. 5-B: Photomicrograph (× 200) shows nidus of more mature lesion. In the fibrous tissue, there is relatively little osteoid. There are numerous well-formed but atypical trabeculae of bone, which is irregularly calcified.

in sixty-five arthrotomies performed for chronic knee complaints. In the same year, Cave, Rowe, and Yee reported that, in 124 arthrotomies performed at an Army hospital, they saw nine cases in which the only cause for the symptoms was the degenerative lesion of the patellar cartilage.

The youngest patient in whom chondromalacia of the patella has been diagnosed clinically was a ten-year-old girl,—a case reported by Hinricsson. However, the youngest patients in whom the diagnosis was verified at operation have been thirteen years of age. In the present study, the youngest patient was a thirteen-year-old girl with cerebrospastic quadriplegia, whose patella was excised because of degenerative lesions of the articular surface (Fig. 4).

Site of the Patellar Lesions

The earliest detectable lesions are most frequently located on the medial facet, less frequently in the center, and occasionally on the lateral facet of the patella. In severe cases, the entire articular surface may be involved.

This predilection of the disease for these different sites has been explained by Wiberg on the basis of the peculiar anatomy of the patellofemoral joint. He made cross sections and roentgenographic studies of knees at different angles of flexion. He was able to show that, when the knee is flexed 20 to 50 degrees, the whole of the lateral facet and only a small part of the medial facet of the patella are in contact with the articular surface of the femoral condyles, whereas the greatest stress is on the central longitudinal ridge. As the flexion of the knee is increased, the pressure on the ridge diminishes, until at 90 degrees it

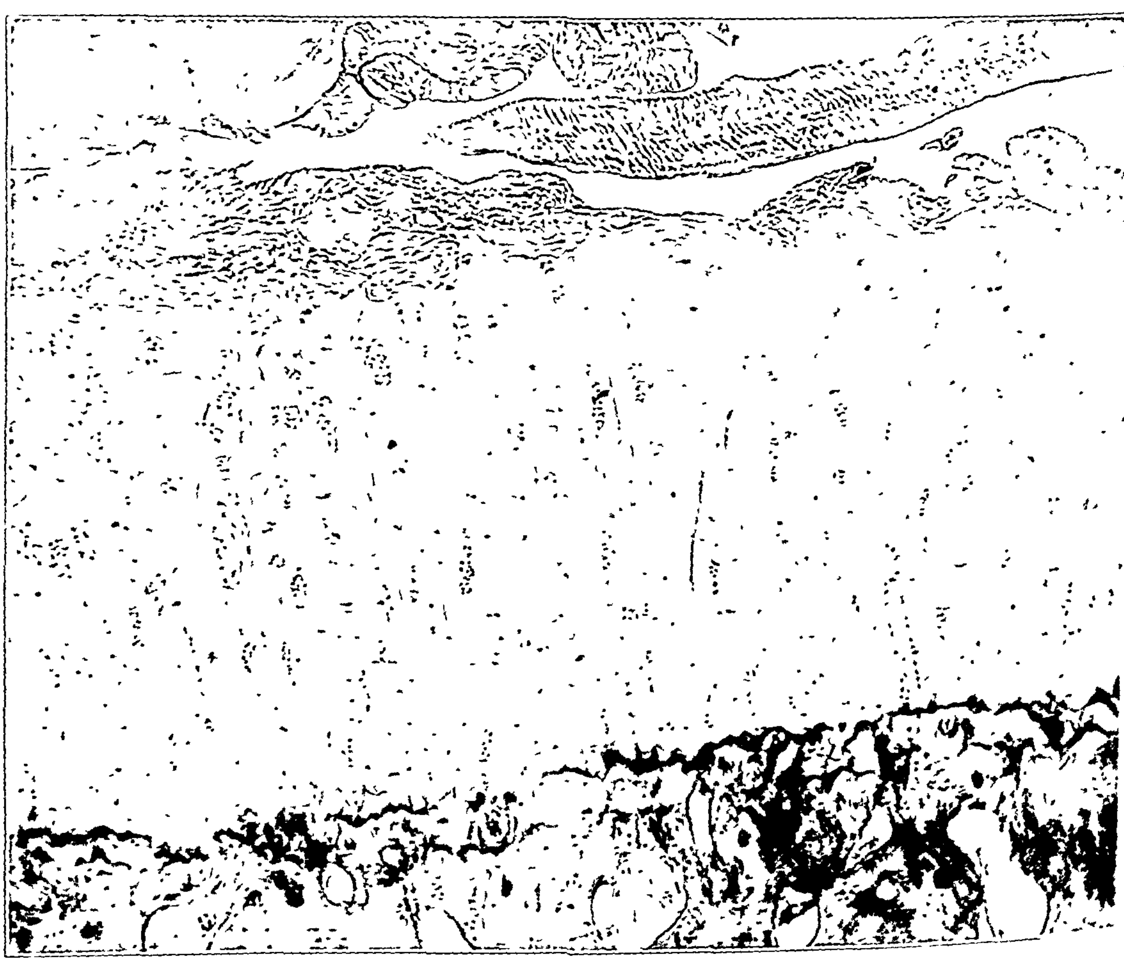

Fig. 2-A

Bessie M., aged forty-four. Advanced chondromalacia of the patella, with fibrillation and fragmentation of the superficial layer of the cartilage, and with undermining of the ulcerated area.

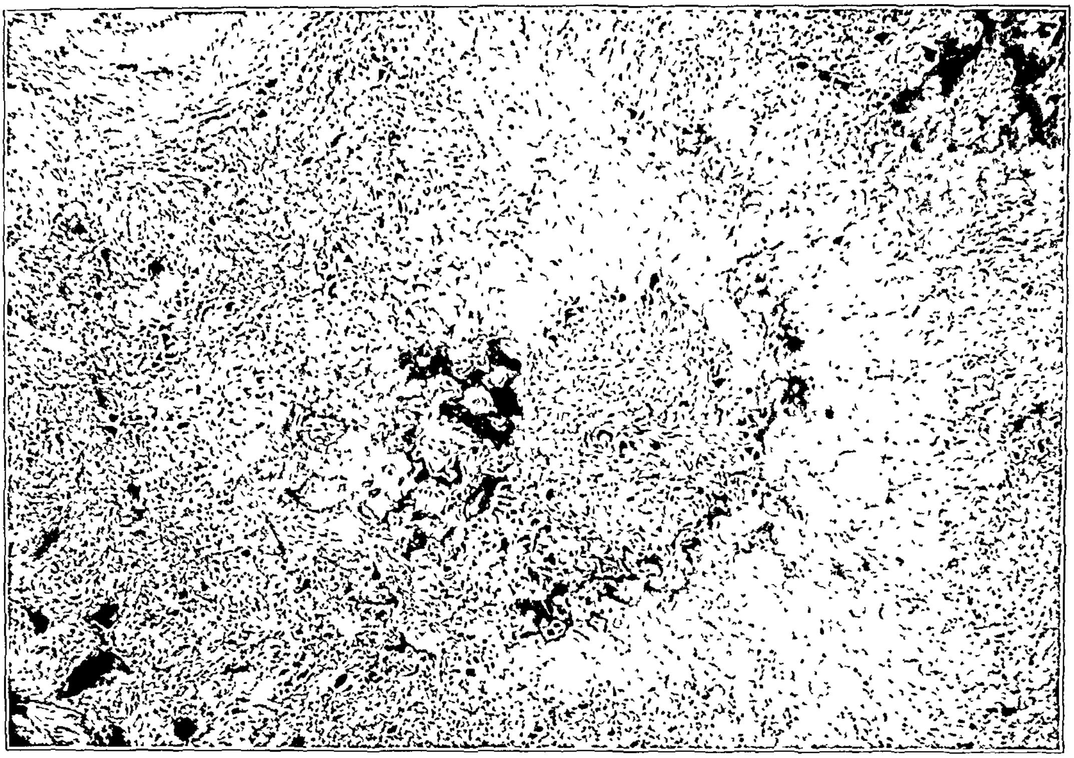

FIG. 6-C

Case 5. Higher-power photomicrograph (× 52) of the middle nidus. The core of vascular fibrous tissue containing giant cells is surrounded by a wide zone of osteoid tissue. Irregular calcification is seen in this ring and also at the periphery.

of the left thigh and knee of eight months' duration. There was no preceding incident of disease or trauma. The pain was never completely absent, had grown steadily worse, and was most severe at night, when it prevented sleeping.

Physical examination disclosed tenderness in the subtrochanteric region of the left femur. Internal rotation of the left hip was limited; atrophy of the thigh muscles was present; and the patient walked with a definite limp. Laboratory tests produced results which were all within normal limits.

The roentgenogram revealed a definite sclerotic lesion in the center of the greater trochanter (Fig. 5-A). It was round and quite well demarcated from the surrounding bone. In the middle was a tiny area of increased density. There was relatively little hypertrophy of the surrounding bone.

Operation showed a small pocket in the ossification center of the greater trochanter, from which grayish fibrous material was easily curetted. The incision healed by first intention, and there was no growth in the cultures made in the operating room. The patient was at once relieved of her complaints, and is still asymptomatic six years later.

Sections of the material taken from the cavity showed the typical structure (Fig. 5-B). The fibrous-tissue stroma was quite dense; it contained many large capillaries and a great many multinucleated giant cells. Osteoid tissue was present, but it was not predominant. Ossification was well advanced, and there were numerous, fairly heavy, irregular trabeculae of immature bone.

This case is remarkable in that the lesion was in an epiphysis.

CASE 5. J. W., a three-year-old boy, had had pain in his left leg for two months before he was seen in August 1946. After one month, a lump had appeared on the upper portion of the tibia, and soon this had become tender. Three weeks before his admission, he began to limp and to waken at night, crying with pain. There was no history of trauma or infection.

Physical examination revealed a firm tender swelling over the upper portion of the left tibia. This area was definitely warm, but not red. The patient walked with a limp, and there was atrophy of the left thigh muscles. Laboratory examinations produced normal results.

The roentgenogram showed a long oval area of decreased density in the anterolateral portion of the upper left tibia (Fig. 6-A). The anterior cortex was expanded, and there was a narrow shell of sclerotic bone surrounding the whole lesion.

At operation, the site of the lesion was clearly marked by roughened periosteal new bone. Total excision was performed with a motor drill. The wound healed without incident, and cultures of the bone produced no growth. The patient was immediately relieved of pain and has remained so.

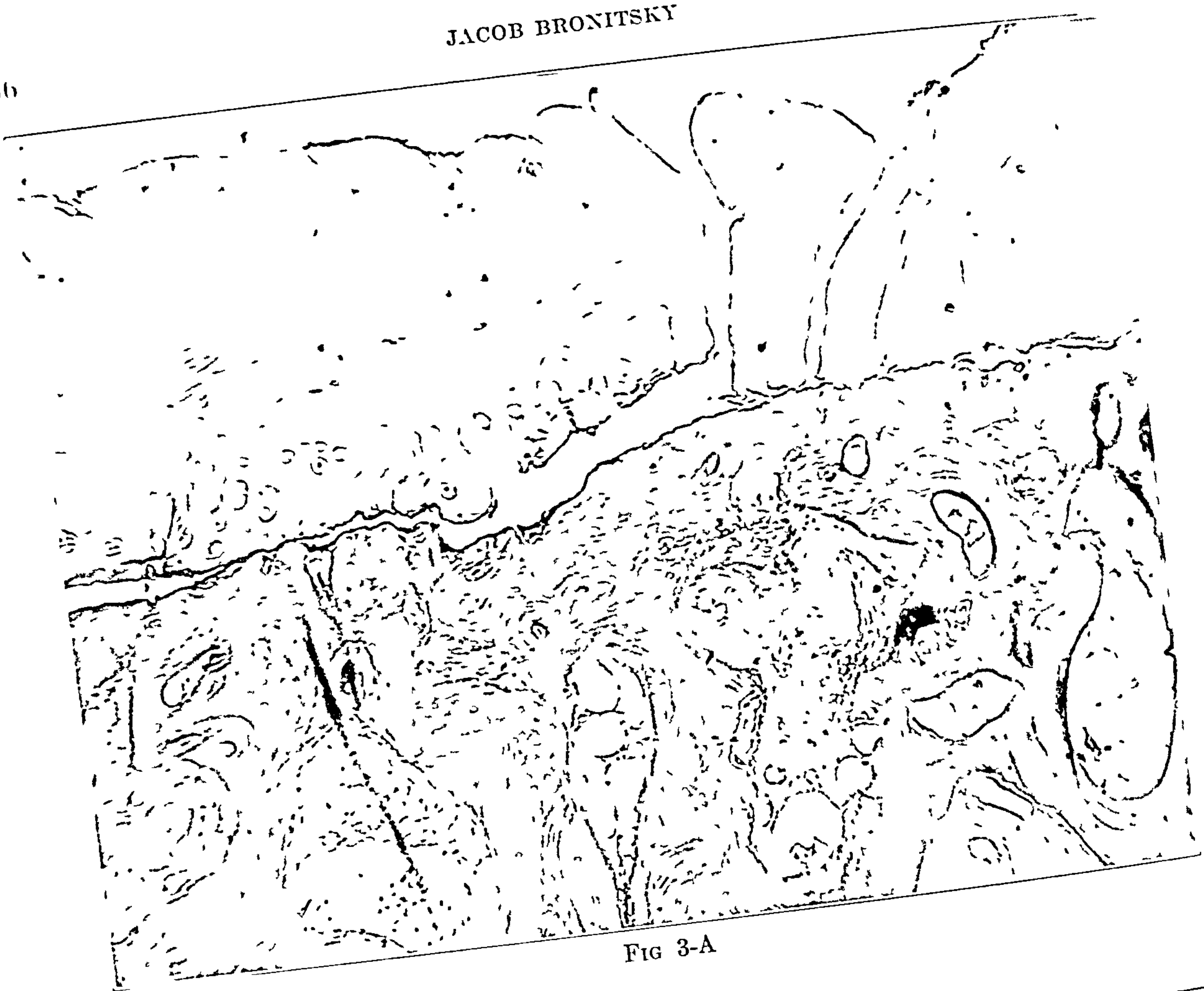

Fig 3-A

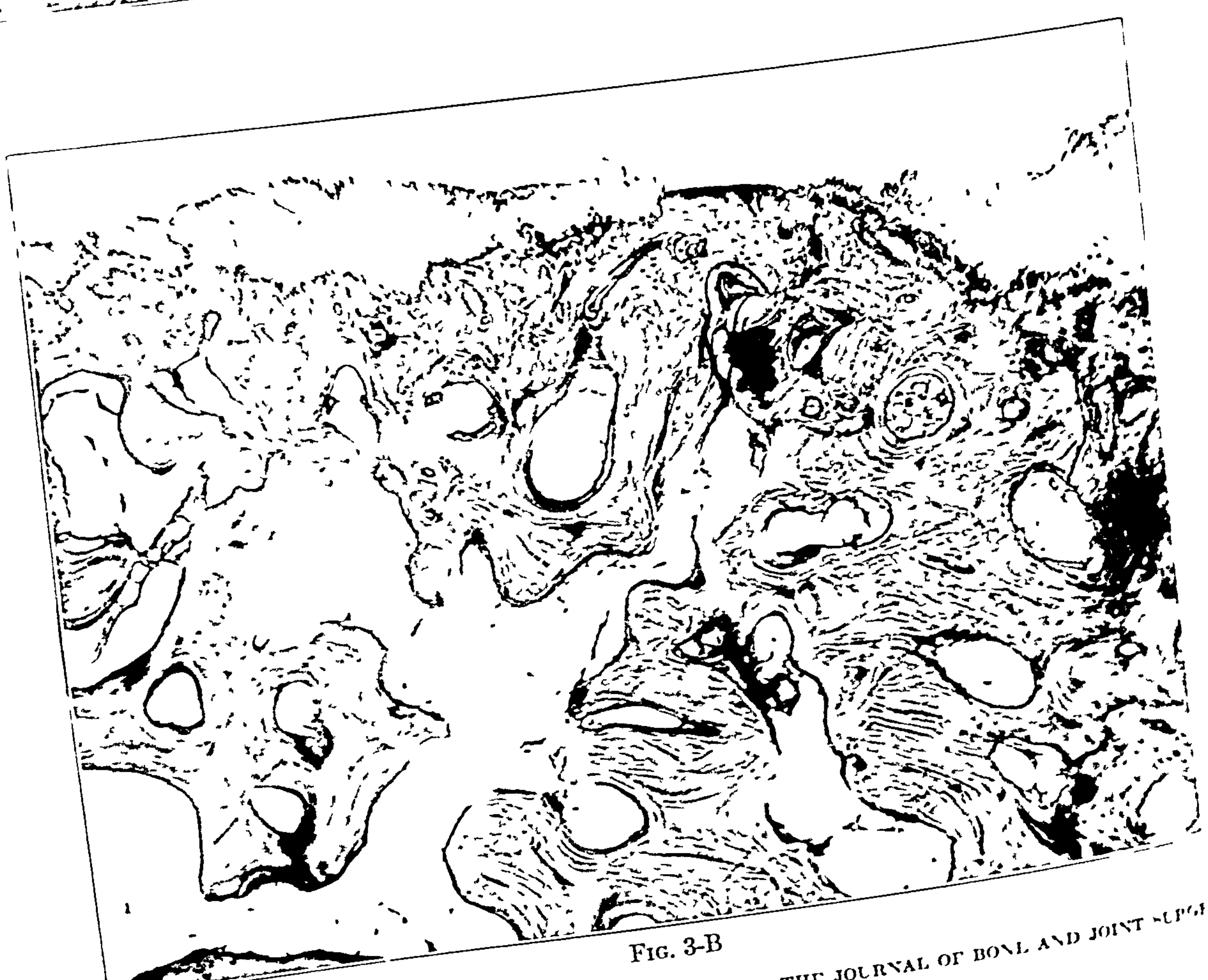

Fig. 3-B

If additional proof were needed, it is certainly amply furnished by the constancy of the distinctive pathological findings. In no case has evidence of either acute or chronic infection been found. The lesions are always sharply demarcated from the surrounding hypertrophied regional bone. The bone immediately surrounding the nidus might possibly be confused with the bone adjacent to an abscess, because the spaces are filled with fibrous marrow which often contains scattered foci of round cells. This picture does not indicate infection, since it is seen in the reactive zone about many different types of lesions. It is also to be noted that the typical tissue of an osteoid osteoma has never been seen in conjunction with a proved abscess, even in those relatively indolent small abscesses which sometimes occur in patients with multiple foci. Osteoid osteomata are always composed of the same few elements: a background of vascular fibrous stroma containing multinucleated giant cells, and osteoid tissue which is irregularly calcified. The lesions differ from one another only in the pattern in which these components are arranged. They are not related to the activity of the hematopoietic tissue, for they occur with no apparent selectivity in fatty and in active marrow, in the cortex, and even just beneath the periosteum. To date no one has found an osteoid osteoma in the scapula, clavicle, or cranium. Case 4 of this report is the only one in which the lesion was located in an epiphyseal ossification center.

Osteoid osteomata, unlike other benign tumors, are never larger than a centimeter or so in diameter. Once they have reached a mature state they do not grow, although the hypertrophied regional bone may increase to form a large mass. Furthermore, it is not only unusual for benign tumors to be painful, but the pain of osteoid osteomata is out of proportion to their small size.

Nevertheless, in consideration of all the facts, we agree with Jaffe that the osteoid osteoma is not of infectious origin, but is probably best interpreted as a benign tumor.

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is progressively reduced. The subchondral bone shows no conspicuous changes until the overlying articular cartilage has become markedly altered. When the erosion extends for a considerable distance into the hyaline matrix, the marrow of the subchondral bone responds with various degrees of fibrous proliferation; fibrous tongues often extend through the zone of calcification. In close proximity to this newly formed fibrous tissue, there may be found cartilage and bone. Occasionally, an isolated mass of cartilage will be found in the marrow spaces of the subchondral bone.

Clinical Symptomatology

The patient with chondromalacia of the patella usually has a history of chronic knee discomfort of varying degrees of severity. The usual complaint is of pain, frequently accompanied by weakness and a tendency of the knee to buckle. This is noted especially when climbing a hill or walking up and down stairs. Often there will be difficulty in fully extending the knee. Repeated momentary locking of the knee may be present. This is not a true locking. The patient experiences severe pain of a few seconds' duration, which may pass away entirely or may be followed by an effusion into the joint. Actual locking may occur, and it is caused by free bodies which have broken loose from the surface of the patella. Frequently, the knee aches, especially after sitting for some time in one position or with the legs crossed. Occasionally the patient will complain that the knee is stiff on arising in the morning and limbers up only after walking.

Crepitation of the patella has been emphasized as the most characteristic sign of this disease. Aleman stated that the location of the crepitation under the patella is pathognomonic. Karlson believed that an experienced examiner can make a diagnosis of chondromalacia of the patella on the basis of the location, hardness, coarseness, and quantity of the crepitation. The crepitation can be elicited with the patient supine, by extending the knee from a flexed position. Sometimes, in order to bring out the crepitation, it will be necessary to have the patient stand up and bend the knee, while the examiner keeps his fingers on the patella. The crepitation has been described as varying from a single click or a soft velvet-like sensation of roughness, to a creaking, crunching, grating sound, which can be heard at a distance of several feet. However, Øwre has been able to demonstrate that degeneration of the patellar cartilage can exist in the absence of crepitation. According to him, crepitation indicates cartilage degeneration, but the absence of crepitation does not rule it out. Fluid in the knee might separate the contacting surfaces.

Pressure pain over the patella is often present. This is elicited either by pressure on the patella with the knee in flexion of 45 degrees or, in the extended and relaxed knee, by pressing the patella against the medial femoral condyle. This pain has been described as a dull, disagreeable, aching pain, which is comparable to a toothache.

Frequently the synovial membrane is thickened and tender, especially over the medial border of the patella and over the plicae alares.

Other symptoms that may occur are effusion into the joint, swelling of the subpatellar fatty tissue, and atrophy of the quadriceps.

Aspiration of the knee effusion will usually show a clear fluid; seldom will it be cloudy. There is no evidence of infection, and occasionally pieces of cartilage will be found in the fluid.

Roentgenograms are of almost no help in making the diagnosis in the early stages. The evidence of osteophyte formation will verify the presence of degeneration of the articular cartilage; but, in a large number of cases, even the osteophytes do not show up on the roentgenograms. Haglund described an indentation of the patellar cartilage which he attributed to contusion of the articular surface. Läwen and others have been able to show that this indentation is a frequent finding and has no relationship to trauma or to chondromalacia of the patella.

CHONDROMALACIA PATELLAE

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REVIEW OF THE LITERATURE

Terminology

The term "chondromalacia patellae" applies to a circumscribed degeneration of the articular surface of the patella, as evidenced by softening, fibrillation with eventual fissuring, and erosion of the cartilage.

Büdinger, in 1906, was the first to describe this condition as "*traumatische Knorpelrisse*" (traumatic fissuring of the cartilage). To König has been given credit for the first use of the term "chondromalacia patellae" in the literature (1924). Although Aleman has claimed that he has been using this terminology since 1918 in his clinical case records, his report on *Chondromalacia posttraumatica patellae* did not appear until 1928. The disease has been further described as "*fissurale Knorpeldegeneration*" [14, 30] (fissuring cartilage degeneration), "*traumatische Chondropathie der Patella*" [8, 17, 21, 33], "chondritis of the patella", "traumatic chondritis" [10], "traumatic fibrillar degeneration" [20, 31], "traumatic degeneration of the articular cartilage" [38], and "traumatic osteochondritis" [11].

The term "chondromalacia patellae" has recently become widely accepted [6, 9, 22, 23, 24, 28, 34, 37] and is being used almost exclusively in the Scandinavian literature to describe this disease. It will also be used in this report.

Etiology

Although chondromalacia of the patella has been recognized for forty years, there is still a lack of complete agreement among observers as to the etiology.

Trauma as the primary factor for the degeneration of the patellar cartilage was suggested by Büdinger in 1906 and was accepted by many of the earlier authors, such as Axhausen (1919), H. Fründ (1926), and Aleman (1928).

However, in many patients, a history of trauma could not be elicited. Aleman explained these cases on the assumption that the patients sustained minor injuries during childhood, which could not be recalled. These minor traumata were sufficient to break the smooth surface of the cartilage, which is known for its inadequate power of repair. The continuous wear and tear of the normally functioning joint further aggravated the damage. Those cases of patellar degeneration with no or negligible clinical symptoms referable to the knee, Aleman termed "*latente Chondromalazie*"; those with clinical manifestations he called "*manifeste Chondromalazie*". But Karlson, in 1939, when he reviewed sixty-two cases, which included twenty cases operated upon earlier by Aleman, concluded that his findings could not prove Aleman's contention that chondromalacia of the patella was always due to trauma. In an investigation of 604 patients, Hinricsson, using Aleman's clinical criteria for diagnosing the disease, also found a discrepancy between the frequency of trauma and the presence of chondromalacia of the patella; only two-thirds of his cases showed agreement.

Other authors have agreed with Kulowski that, although trauma is the primary exciting cause, a predisposed constitution and the peculiar mechanism of the knee joint also play important roles in the formation of the degenerative changes found in chondromalacia of the patella.

The similarity between chondromalacia patellae and degenerative arthritis has been recognized by many observers. Läwen (1925) and König (1928) suggested the early

Group VI includes two cases: one of a generalized atrophic arthritis; the other of mono-articular synovitis of the knee, following the incision and drainage of a Brodie's abscess in the distal end of the tibia of the same side.

It is obvious that the above division is an artificial one, as there is no sharp demarcation between the different phases of the disease.

At the time of operation, the ages of the female patients ranged from thirteen to fifty-five years; those of the male patients ranged from nineteen to fifty years. One patient was thirteen, another sixteen, and two patients were nineteen years of age. Fourteen (48.3 per cent.) were in the third, and five were in the fourth decades of life. The remaining six patients were over forty years of age. The average age of the twenty-nine patients was thirty years.

A history of acute trauma was denied in eight (25.8 per cent.) of the thirty-one knees involved. The types of trauma reported in the remaining twenty-three cases were as follows:

Direct blow to the knee	12 cases
(Includes one case of multiple sclerosis with a history of repeated falls)	
Twisting injury to knee	4 cases
Tackled or clipped, while playing football	3 cases
Injured while pole-vaulting	1 case
Traumatic dislocation of the patella	2 cases
Recurrent dislocation of the patella	1 case

In the twelve cases of direct trauma to the patella, the force of the blow varied from a kick in the knee by a cow to any force sufficient to fracture the patella. The average history was that of striking the knee against a hard surface. A comparison of Group I with the other groups, especially Group V, shows that a history of trauma is of little value in differentiating between pure chondromalacia of the patella alone and other coexisting lesions. The typical history for the occurrence of a torn meniscus is often that the patient was tackled or clipped while playing football. In the three cases of this study, only one patient had a torn meniscus. The other two showed no involvement of the menisci.

The following three cases emphasize how difficult it is at times to evaluate the relationship of trauma to degeneration of the patellar cartilage.

CASE 1. Gerald H., aged twenty, injured the left knee while pole-vaulting in 1925. In 1927, he jumped five feet and again injured the knee. After these accidents, he had had recurrent locking and pain over the lateral aspect of the knee.

On January 13, 1933, arthrotomy was performed for the removal of the lateral meniscus. No other pathological changes were noted in the joint, although it was eight years after the first trauma and six years after the second.

On August 9, 1933, only seven months later, another arthrotomy was performed; a typical chondromalacia of the patella, with involvement of the synovial membrane, was then evident.

On May 7, 1934, the patient returned, stating that, since February 28, 1934, he had had pain in the opposite knee with swelling and locking and a tendency to "give" on weight-bearing. There was no history of acute trauma; and an arthrotomy, on May 14, 1934, revealed that the medial meniscus was loose, and there was a slight erosion of the medial condyle of the femur. The patella was normal.

CASE 2. Cleo G., aged twenty, stumbled and twisted her left knee on February 12, 1931. This resulted in pain and swelling. A leg brace brought no relief from the pain.

On February 5, 1932, an arthrotomy showed that the knee was normal, except for a redundant strip of fatty tissue, interposed between the articular surfaces of the femur and the tibia. Although this was one year after the trauma, there was no evidence of chondromalacia of the patella.

One year later, on January 26, 1933, arthrotomy revealed a severe degeneration of the patellar cartilage.

CASE 3. Wilma S., aged sixteen, struck her chin against her left knee, while gliding down a fire-escape tube on October 20, 1939. She had moderate pain in the knee. She injured the knee again, while skating, on October 30, 1939.

On July 31, 1940, an arthrotomy, performed after a diagnosis of internal derangement of the knee, revealed a hypertrophic fat pad. Synovial membrane and patella were normal. At this time, nine months after the trauma, there was no evidence of degeneration of the patella, but on January 21, 1942, eighteen months later, arthrotomy revealed chondromalacia of the patella.

strength, but was repeated often or was maintained over too long a period, an impairment of elasticity resulted. Since he believed that the normal elasticity of the cartilage, and its resulting pumping action, was essential to its nourishment, he concluded that "nutritional disorders, due to unfavorable loading, may be one of the main reasons for pathologic changes in the cartilage of the patella". Furthermore, from his studies on the chondroitin-sulphuric acid content of cartilage, he concluded that fissures develop in an already altered cartilage.

Lanier, in 1946, concluded from his experiments with mice that mechanical factors were subordinate in the production of degenerative joint disease. He agreed with the suggestion made by Bennett, Waine, and Bauer that the metabolic processes of aging cartilage will have to be comprehended before the problem of degenerative joint diseases can be solved. Sundt, in 1938, stated that chondromalacia of the patella is a constitutional disease, and suggested that the primary cause was an injury to the synovial membrane, which then produced an abnormal fluid. He assumed that, since the articular cartilage to a large extent received its nourishment from the synovial fluid, an abnormal composition of the latter would cause nutritional disturbances in the cartilage and lead to its degeneration.

Fig. 1

Thomas M., aged twenty-one. Chondromalacia of the patella.

In 1945, Cox expressed the opinion that the true pathological change was in the underlying cancellous bone, and that the change in the articular cartilage was entirely secondary.

To summarize the present trend of thought:

1. Our knowledge of the physiology and nourishment of cartilage is still incomplete.
2. Degeneration of cartilage without trauma does exist.
3. Acute trauma or static deformities can influence the origin and progress of the disease.
4. The question of constitutional disposition and heredity as etiological factors is still unsettled.

Incidence of Chondromalacia of the Patella

In 1927, Aleman reported that, in 220 arthrotomies performed on soldiers in the third decade of life, he found in one-third of the cases a focus of softening and fissuring of the articular surface of the patella.

Darrach, in 1935, reviewed 157 operations for internal derangement of the knee and found a diseased patella in thirty-six patients. In 1939, the same author noted, in 376 arthrotomies, that in 6.8 per cent. of those patients with a degenerative lesion of the patella, it was the only demonstrable pathological change found in the knee.

Hilzensauer, in 1936, reviewed 1,000 arthrotomies performed at the hospital in Graz, Austria. He found chondromalacia of the patella in forty-eight cases. Chaklin, in 1939, found thirty-eight cases in 159 operations on the knee.

In recent years, a number of cases of chondromalacia of the patella have been reported at various military hospitals. At a Naval hospital, Anderson, in 1944, found ten cases in fifty successive arthrotomies. At an Army hospital, Soto-Hall, in 1945, found twelve cases

Points of tenderness were reported in twenty-two case records. They were present in nineteen cases (86.4 per cent.) and absent in three cases. Two of these three patients in whom there was no point of tenderness were found in Group V.

If the six patients of Group V are excluded from the study of this symptom, fifteen of sixteen cases remain in which there was a point of tenderness. Fourteen of these cases had a point of tenderness somewhere along the medial aspect of the knee joint, located as follows:

Over the anterior insertion of medial meniscus	5
Medial to the patella	5
Along the tibial collateral ligament	2
All around the patella	1
To each side of the patellar ligament	1

In one case, the point of tenderness was in the infrapatellar area.

Crepitation or grating of the patella was present in twenty-three of the twenty-five case histories (92 per cent.) which reported this sign, but insufficient data precluded any attempt to evaluate the quality of the sound. Of special interest is Group I, in which the presence of this sign was noted in five of the six patients.

Selda R., in Group II, had no crepitation, although the synovial membrane was described as "grape-like".

When Wilma S. (Group I) was examined previous to arthrotomy, no grating was heard. The patella was found to be normal. Examination previous to the second arthrotomy revealed soft grating. The patella then showed a marked chondromalacia.

Swelling of the knee was looked for at the time of preoperative examination in twenty-four cases. Nine patients (37.5 per cent.) showed this swelling. In fifteen cases (62.5 per cent.), effusion of the knee was not demonstrable clinically. The nine cases with positive swelling were distributed in the groups as follows:

Group I	None of 4 cases
Group II	2 of 4 cases
Group III	1 of 5 cases
Group IV	3 of 5 cases
Group V	1 of 4 cases
Group VI	2 of 2 cases

In one case of osteochondromatosis, the firm nodules were palpable.

With the exception of the cases of osteo-arthritis, in which the presence of osteophytes could be demonstrated, all roentgenograms in this study were reported as negative for bone or joint pathological changes.

One exception, Iris B., a thirteen-year-old girl with cerebrospastic quadriplegia, showed a marked indentation in the articular surface of the patella; this was probably due to the continuous pressure of the patella against the femoral condyle (Fig. 4).

RESULTS OF OPERATION

All patients were operated upon only after conservative therapy had failed to give relief.

Several operative procedures have been recommended in the literature for the treatment of chondromalacia of the patella. All reports of these procedures have been favorable. In this series, four different surgical procedures were used:

1. Chondrectomy, in which the degenerated cartilage was shaved off with a sharp blade until normal-appearing cartilage was reached.

2. The same procedure was used, but the patellar surface was then covered with synovial membrane.

3. Patellaplasty, in which the entire patellar cartilage and subchondral bone were removed with a saw. This left a bony shell, the raw surface of which was then covered

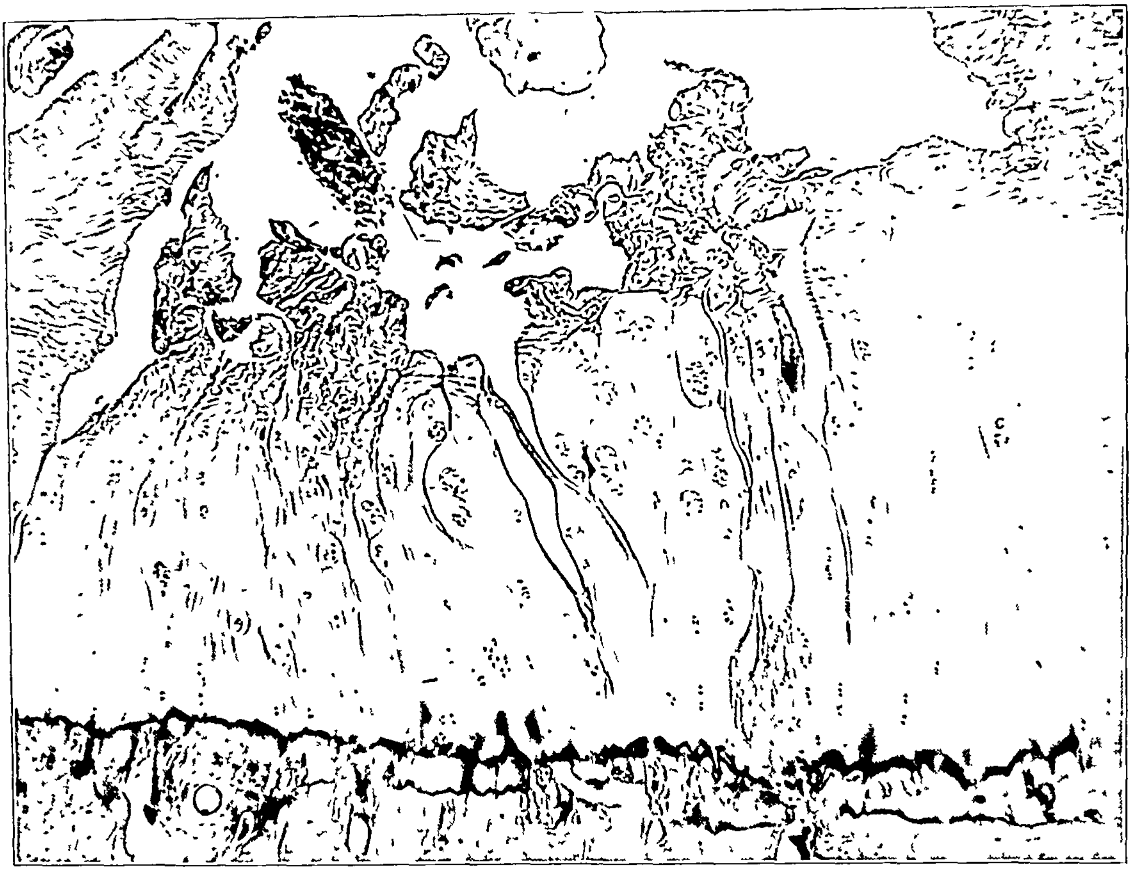

FIG. 2-B

Center of ulceration seen in Fig 2-A, showing the fissures reaching into the deeper layer of the cartilage. Weichselbaum lacunae are evident. The subchondral bone is sclerotic, with a double line of calcification. Small tongues of fibrous tissue have penetrated the subchondral layer.

disappears completely, for at this angle the patella reaches the intercondylar notch of the femur. At this point, contact is maintained only by the larger lateral and the smaller medial facets. During flexion, the lateral patellar facet continues in good congruence with the lateral femoral condyle, while the medial facet of the patella, from an angle of 90 degrees and upward, opposes a convex surface to the convex femoral condyle.

Pathology of Chondromalacia Patellae

The degenerative changes found in cartilage have been studied and described by many investigators. To summarize:

Gross Examination: In the early stage, the cartilage loses its bluish-white, shiny, translucent appearance and becomes opaque, yellowish, and softer than normal. As the degeneration proceeds, cracks and fissures appear, which give a frayed appearance to the surface. With the continued progress of the disease, the cartilage is gradually ground down, until the underlying bone is exposed. The exposed bone soon becomes sclerotic and eburnated. In extreme cases, the entire articular surface will be denuded of cartilage. Marginal osteophytes have been shown to appear relatively early and, according to Øwre, will be best developed in those areas where the degenerative lesion has reached the cartilaginous edge. Frequently, the synovial membrane is secondarily involved and shows evidence of non-infectious inflammation.

Microscopic Examination: The early lesions are featured by fibrillation of the superficial layer of the cartilage; the deeper adjacent layer is swollen, as revealed by its abnormal staining, and contains relatively few cells. The individual cells degenerate, increase in size, and are heaped together in small groups. As the clefts and fissures form, the large cell clusters or lacunae of Weichselbaum appear in the vicinity. The thickness of the cartilage

TREATMENT OF UNUNITED FRACTURES BY ONLAY BONE GRAFTS WITHOUT SCREW OR TIE FIXATION AND WITHOUT BREAKING DOWN OF THE FIBROUS UNION *

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The most important factors responsible for recent advances in the treatment of ununited fractures have been improvement in the methods of bone-grafting, prevention and control of infection by antibiotics, and the performance of more extensive and finished operations, based on support of the circulation by adequate blood transfusion. The type of operation used varies with many factors,—such as the bone involved, the location of the fracture (whether in the shaft or in the end of the bone), the position of the fragments, and the presence or absence of infection.

The operative technique for ununited fractures of the shafts of the long bones, which have not become infected, has become a standard procedure for the majority of the surgeons of this country. Briefly, it consists of incision at the fracture site, reflection of the soft parts from the exposed side of the bone, breaking down of the fibrous union or pseudarthrosis, separation of the soft parts from the entire circumference of the fragment ends for from 2.5 to 5 centimeters, removal of callus from the fracture surfaces and the medullary canal, correct approximation and alignment of fragments, and then onlay of a broad, long, whole-thickness bone graft, fixation of the graft to the fragments by metal screws, closure of the soft parts, and immobilization of the extremity, by encasement in plaster-of-Paris. The tibia has been the usual source of grafts; but recently iliac grafts have increased in popularity, because of the good results obtained with them in World War II. Metal plates are sometimes used, either in addition to or in place of the grafts.

The rationale of the procedure is as follows: The removal of callus and the freeing of the fragment ends permit reduction and alignment, and stimulate osteogenesis. The graft bridges the fracture and affords internal fixation; and surviving osteoblasts along its periosteal and endosteal surfaces are an additional source of osteogenesis. Bony union and a good functional result are usually obtained.

There are, however, certain drawbacks: The amount of trauma is proportionately great; tissue, including the ends of the bone, may be devitalized; the rigidly fixed graft may become fractured; and infection is more frequent than in clean operations of the same magnitude, performed on soft tissues. These factors are responsible for a certain proportion of non-unions and osteomyelitis. If the fracture is of a large bone and complex, the operative repair may be long, difficult, and bloody; and shock may supervene, with serious consequences, unless this condition is properly managed. Although the objections to this type of procedure have greatly diminished since penicillin and adequate blood transfusions have been used, they are still of sufficient magnitude to justify a further search for simpler operations.

Two common erroneous teachings have retarded the development and acceptance of a much more simplified technique [3, 7], applicable to ununited fractures of the shaft, in which the position of the fragments is quite acceptable were union present. The first misconception is that, in all cases of non-union, the fracture line should be broken down, and the intermediary and medullary callus should be removed from the fragment ends. The second is that the graft should always be firmly anchored to the fragments by screws or encircling ties.

An experience, twenty-four years ago, with an ununited fracture of the mandible

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1947.

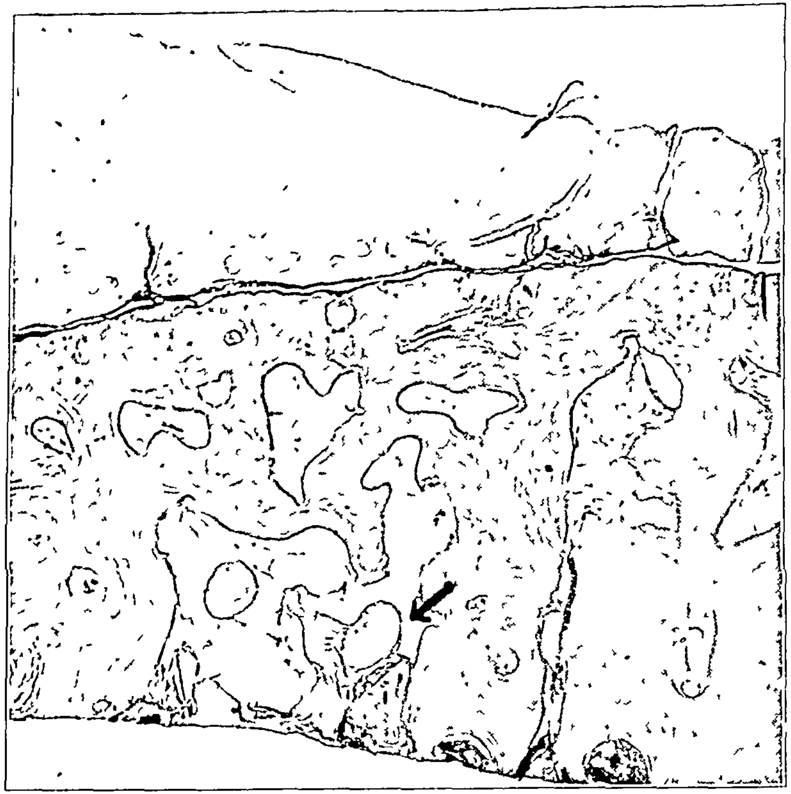

Fig 3-C

Fig. 3-A: Ellen S., aged twenty-one. Severe chondromalacia of the right patella. The cartilage is fissured and is separated from the underlying bone. There are islands of newly formed cartilage over the denuded bone. Islands of fibrocartilage and hyaline cartilage are deeply seated in the marrow spaces.

Fig 3-B. Area from the center of the ulcerated area seen in Fig. 3-A The cartilage is almost completely gone. The subchondral bone shows advanced bone sclerosis and eburnation of the surface.

Fig. 3-C: An advanced case of chondromalacia of the left patella, with an isolated mass of cartilage in the bone marrow indicated by arrow.

Fig. 3-D. A higher magnification of the area in Fig. 3-C indicated by arrow. The cartilage may be seen to be forming new bone.

Fig. 3-D

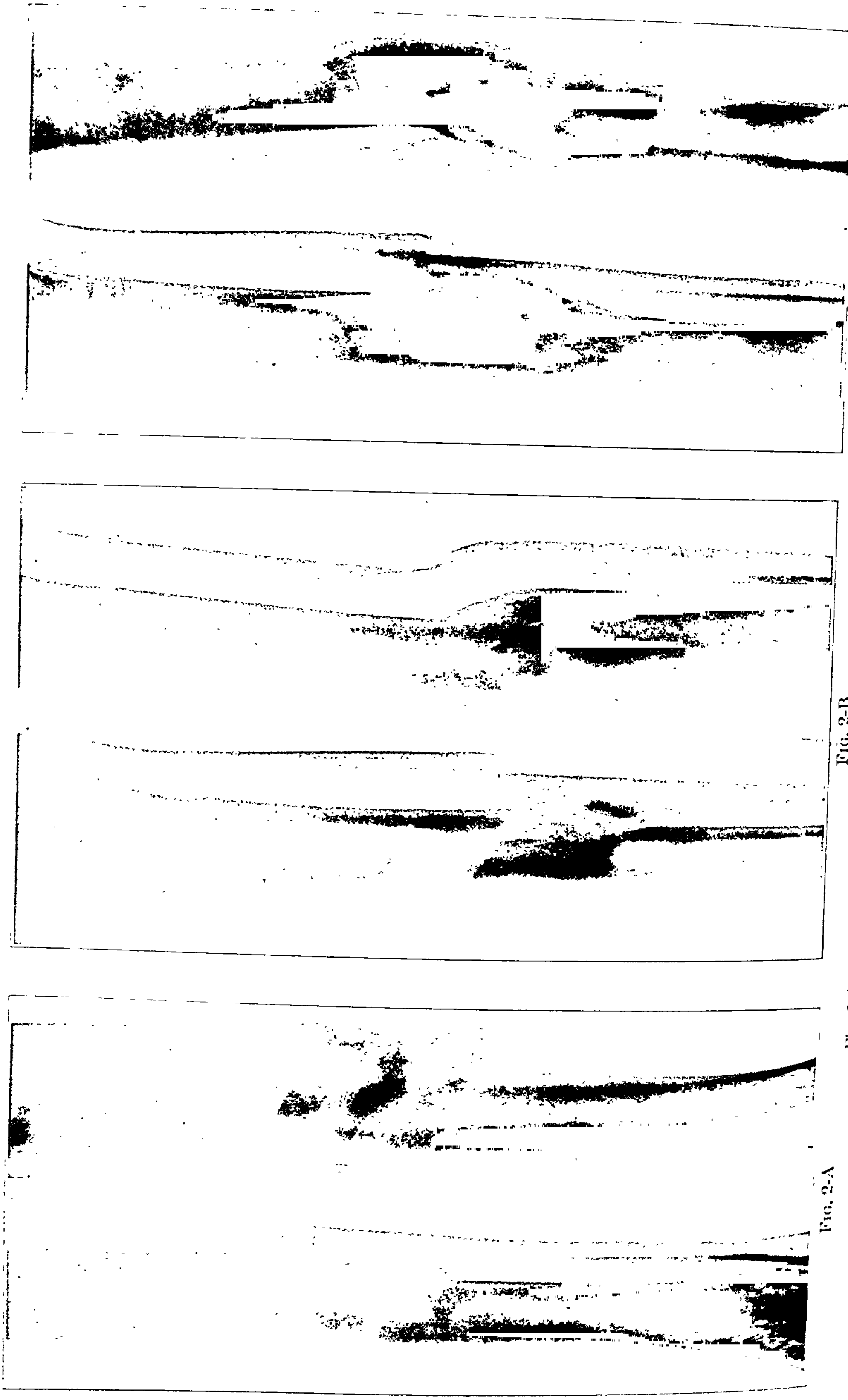

Fig. 2-A

Fig. 2-B

Fig. 2-C

Fig. 2-A: Case 2. Non-union of tibia of one year's duration.
Fig. 2-B: Three months after operation.
Fig. 2-C: One year after operation.

PRESENT STUDY

Although Aleman and Karlson have insisted that the clinical symptomatology described is pathognomonic for chondromalacia of the patella, there are many other observers who find that these symptoms are applicable to several knee conditions. Timbrell Fisher, for example, states that slight adhesions involving the alar fat pads may give rise to a surprising amount of disability in the form of pain, synovial effusion, weakness, tenderness, muscle wasting, and a sensation of "giving way" of the joints, but not as a rule to actual locking. These symptoms are very similar to those described for chondromalacia patellae. He further states that crepitus is caused by the movement of hypertrophied synovial fringes.

The purposes of this paper are:

1. To analyze the relationship between the symptoms and the pathological findings.
2. To evaluate the results of operative intervention in chondromalacia of the patella.

This study is based on case records, borrowed both from the private files of Dr. Arthur Steindler and from the clinical files of the Department of Orthopaedic Surgery, University of Iowa. Only those cases in which the degeneration of the patellar cartilage was verified at operation were included in this study. The case histories of twenty-nine patients were reviewed (these included three cases reported by Kulowski in 1933). There were sixteen female and thirteen male patients. Two female patients had pathological conditions in both patellae. A total of thirty-one knees were involved.

At operation, there was frequently found, besides the patellar degeneration, a coexisting synovitis, a hypertrophied fat pad, free bodies, a torn meniscus, or a combination of several of these conditions.

In an attempt to evaluate the symptoms, the cases were arranged in the following six groups, depending upon the type of pathological involvement found:

Group I includes all cases in which the pathological condition was localized to the patellar cartilage alone. Theoretically, all clinical symptoms produced in this group should be due to the degeneration of the patellar cartilage. There were six patients with an average age of 21.6 years and an average duration of symptoms of 2.7 years.

Group II includes all cases in which an acute or chronic inflammation of the synovial membrane coexisted with the degeneration of the patellar cartilage. This group can be considered as representing a further stage in the degenerative process; it includes four patients with an average age of 29.6 years and an average duration of symptoms of eighteen months. The fifth patient's symptoms had been present for eight years.

Group III includes all cases in which, besides a chondromalacia of the patella, there were found cartilaginous bodies, either enclosed in the synovial membrane or lying free in the joint. As synovial changes were usually present also, these cases might be included in Group II. However, since these bodies could possibly produce symptoms independent of the other pathological changes, these cases were grouped separately. There were five patients in this group with an average age of 22.6 years and with an average duration of symptoms of 2.6 years. The sixth patient, Ellen S., aged twenty-one, had complaints referable to the right knee that had existed as long as she could remember (Figs. 3-A and 3-B).

Group IV includes all cases in which the pathological changes were extensive enough to warrant the diagnosis of osteo-arthritis or degenerative arthritis. There were five patients in this group with an average age of forty-seven years and a duration of symptoms of 2.3 years. The sixth case involved the left knee of Ellen S., mentioned in the previous paragraph (Figs. 3-C and 3-D).

Group V includes all cases in which there was a torn meniscus, regardless of the other degenerative changes in the knee. Cases with the diagnosis of hypermobile meniscus were not included in this group. There were six patients with an average age of 29.7 years and an average duration of symptoms of five years.

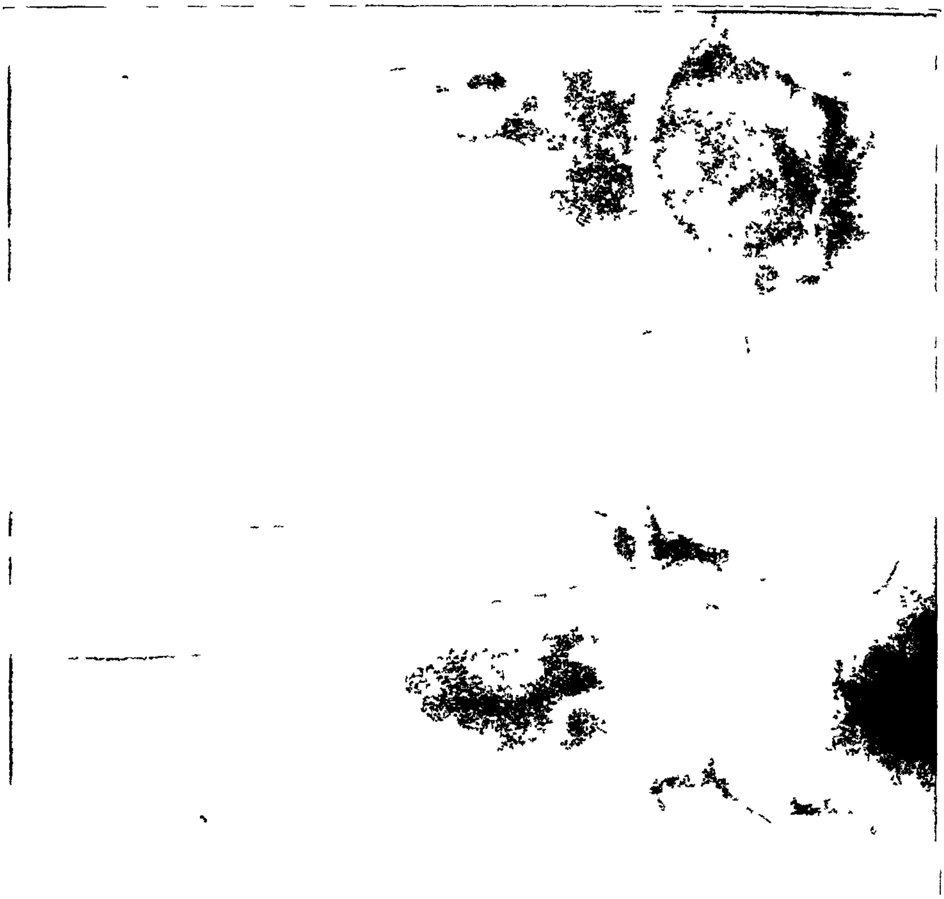

Fig. 3-C
Ten and three-quarters months after operation

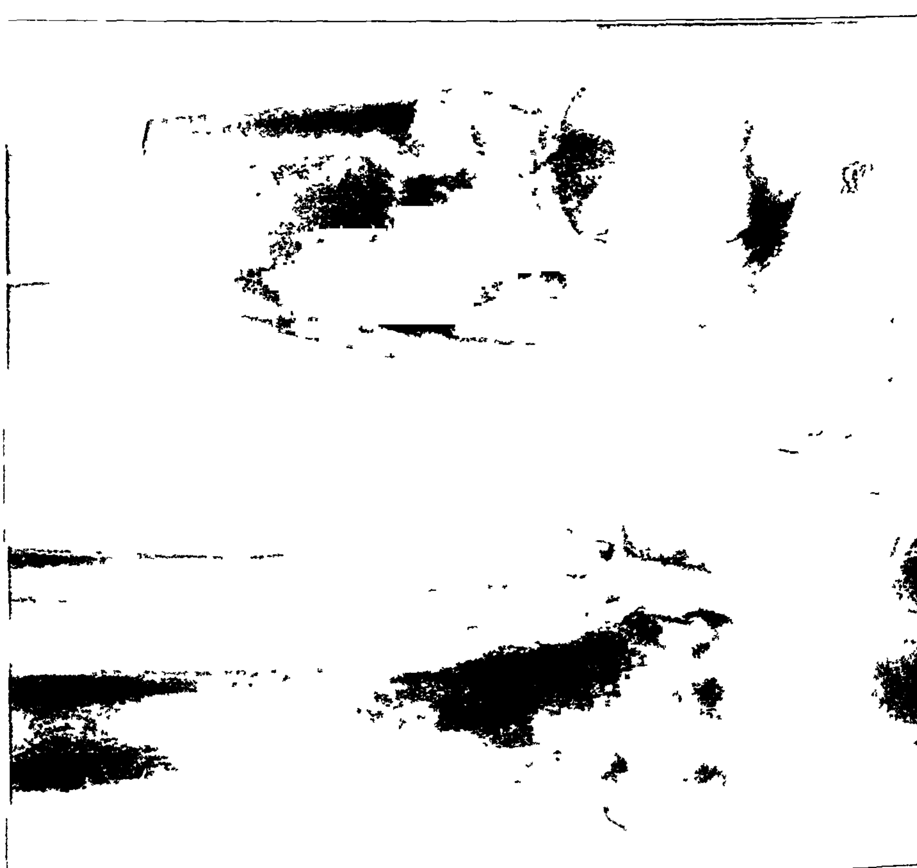

Fig. 3-B
Three months after operation

On the other hand, two patients with traumatic dislocation of the patella showed marked chondromalacia of the patella, five months and one year, respectively, after the trauma.

Observation of such cases raises the question of the relationship between the duration of complaints and the degree of degeneration found at operation.

Although the number of cases is insufficient for definite conclusions, it was noted that, in the younger patients of the group, the longer the duration of symptoms, the greater was the degree of degenerative involvement of the patella. In the older patients with clinical evidence of osteo-arthritis, such correlation was not evident.

It is not known definitely why, during the process of cartilage degeneration, some patients suffer from continuous discomfort, whereas in others the degenerative process proceeds without any, or with relatively minor, symptoms. In the latter group of patients, the duration of symptoms naturally would not be reflected in the pathological findings.

In the traumatic group, there was, apparently, no relation between the duration of symptoms and the degree of degenerative changes. The amount of degeneration found depended on two factors, both of which are frequently difficult to evaluate. The pathological findings depend, first, upon the amount of degeneration present at the time of the accident and, second, upon the severity of the trauma. Traumatic dislocation of the patella seems to be most detrimental to the cartilage.

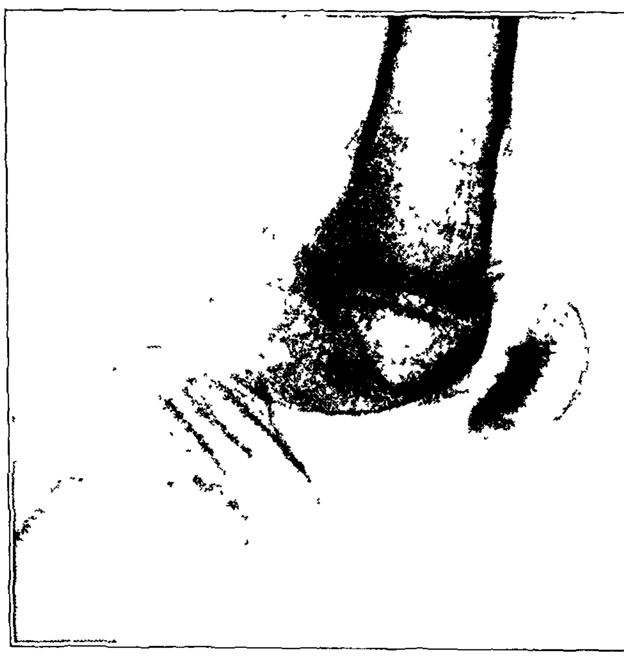

FIG. 4

Iris B., aged thirteen, a cerebrospastic quadriplegic. Showing the marked indentation of the right patella, probably due to the continuous pressure of the patella against the femoral condyle.

Phyllis C., aged twenty, had had injuries to both knees. In 1935, she had twisted her right knee while playing basketball. This resulted in serious discomfort, which was almost continuous. She twisted and injured the left knee in 1939.

On April 8, 1940, five years after the first injury, an arthrotomy was performed on the right knee, and on May 29, 1940, eight months after the second injury, an arthrotomy of the left knee was done. Although the interval since the trauma varied in the knees, the pathological findings revealed almost the same marked fibrillation of both patellae. A free body was found in the intercondyloid notch of the right femur. On the lateral condyle of the same femur was a small defect, which had been filled with fibrous tissue.

History of recurrent effusions was not investigated in nine patients; of the remaining twenty-two patients, sixteen reported the presence of recurring effusions, whereas this was denied by six patients; one with recurrent swelling showed normal synovial membrane.

History of weakness or locking in this series includes both true locking and the so-called "staying" or "catching" of the knee.

Twenty-five patients reported this symptom. In nineteen (76.0 per cent.) of these cases, the symptom was present; it was absent in six. It is interesting to note that in Group V, this symptom was absent in two of the six patients.

Gilas Mc. of Group I had true locking three weeks and two weeks prior to admission. The first time locking occurred, it was relieved by manipulation. The second time, it was necessary to apply traction for twenty-four hours before it could be relieved.

Patellar tenderness could not be evaluated, since twenty-three of the twenty-nine case records had no data on the subject.

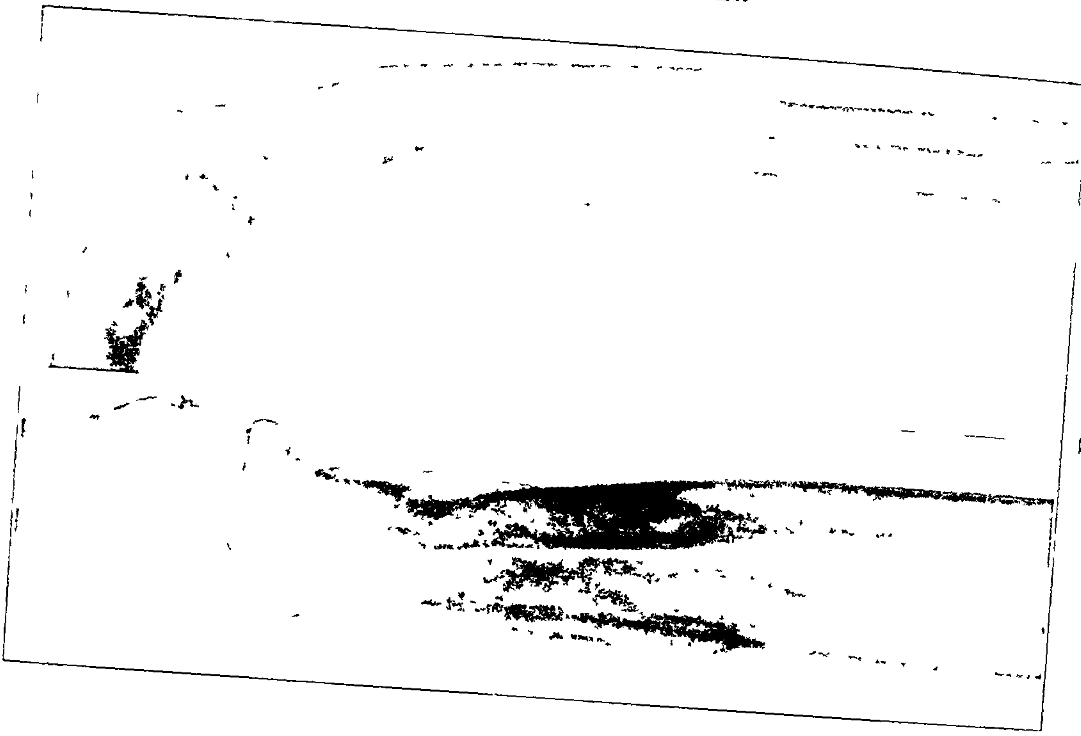

Fig. 5-C

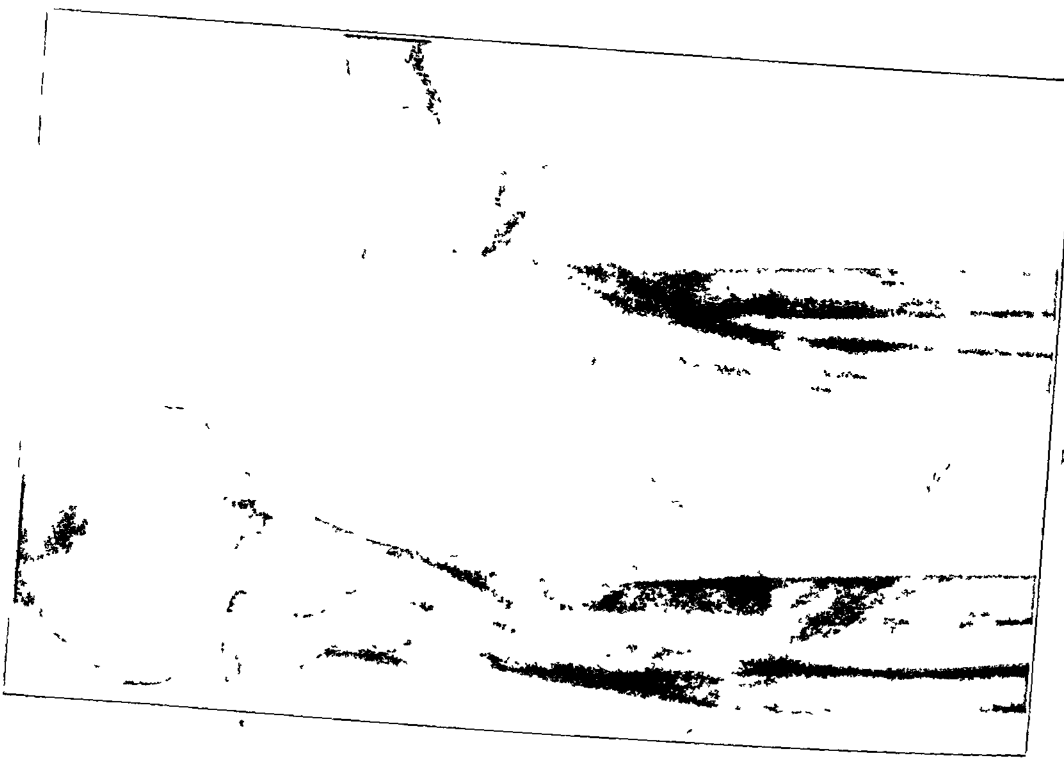

Fig. 5-B

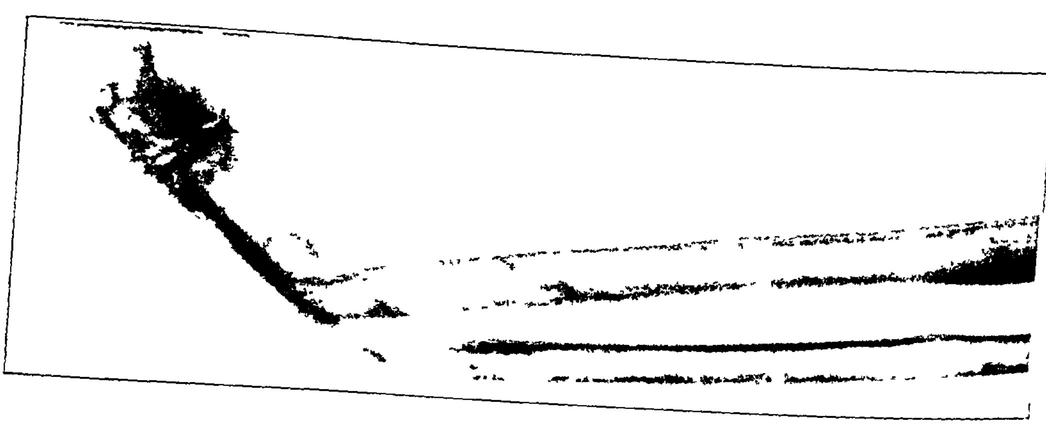

Fig. 5-A

Fig. 5-A: Case 5. Six-month-old fracture of irradiated, atrophic bones.
Fig. 5-B: Three months after application of simple onlay bone graft.
Fig. 5-C: Two years after operation.

with synovial membrane. Where the synovial membrane was degenerated, fascia or quadriceps tendon was used to cover the raw patellar surface.

4. Complete excision of the patella.

In all the cases, any other coexisting pathological condition noted at operation was removed or corrected. Synovectomy for removal of a mildly hypertrophic or congested synovial membrane was not performed.

Eighteen patients were followed from one to seven years after treatment, with an average follow-up of two years and three months; in six of them, the follow-up period was from five to nine months; in four, it was less than five months. In three cases, there was no follow-up, because these patients were sent back to the physicians who had referred them as soon as they were able to leave the Hospital.

The results were tabulated as good or poor, depending upon the patient's subjective response to surgery. The result was considered good when the patient obtained both subjective relief from his complaints and good function of the limb. The result was noted as poor when the patient failed to obtain either satisfactory alleviation of his complaints or good function of the limb. In some, further surgical intervention finally produced relief from symptoms. Subjective improvement was usually noted a short time after operation.

In one patient who was followed for four weeks after treatment, a free body was removed from the knee. In three patients with a follow-up of six weeks, seven weeks, and ten weeks, respectively, a chondrectomy was performed. The results in these last four patients were good, but are not included in this analysis.

Chondrectomy was performed in eight of the cases included in this study with six good and two poor results. Of the two poor results, one occurred in a patient with a coexisting subluxation of the patella. A "reefing" of the capsule was also done at the time of operation. The second patient had a congenital slipping of the patella. At the time the chondrectomy was performed, a hypermobile medial meniscus and a hypertrophic fat pad were removed, and a Goldthwait tendoplasty was performed on the patellar tendon.

In the three cases in which synovial membrane was used to cover the patellar surface after chondrectomy, there were two poor results and one good result. The two poor results occurred in the same patient, Phyllis C. Both patellae were later excised, with a good result in one knee and a poor result in the other.

All four cases in which patellaplasty was performed gave poor results. One patient had multiple sclerosis, a second patient had generalized atrophic arthritis, and in a third case, the synovial membrane was degenerated and plastered down, with a pannus over the femoral condyles and the patellar surface. A strip of the quadriceps tendon was used to cover the raw patellar surface. In the fourth case, Ellen S., both patellae were involved. In the right knee, in which the patellaplasty was done, the result was poor. Arthrotomy was again performed, and the synovial membrane, previously used to cover the patellar surface, was removed. This procedure gave a good result. However, in the left knee, only a hypertrophic fat pad and a free body were removed; the patella was left untouched, and the result was good.

In the six cases in which the patella was excised, there were five good results and one poor result. The poor result occurred in the patient with chronic mono-articular synovitis, following an operation for a Brodie's abscess in the distal end of the tibia of the same extremity. The functional result of the knee was good, but the swelling persisted. In all the cases of patellectomy, the function of the knee was good, except in the one knee of Phyllis C., mentioned previously.

There were two osteo-arthritic cases: Marguerite B., aged thirty-four, in whom a congenital subluxation of the patella was treated with a medial transplantation of the patellar tendon; and Maxine H., aged fifty-five, in whom an arthrotomy was done on the diagnosis of osteochondritis dissecans, and the free body was not found. In both of these cases, the patellae were left intact and the results were good.

the intermediary callus, and the soft parts were sutured. Despite the irradiation damage, the fracture w found to have united, when the cast was removed three months later (Fig. 5-B). A more traumatizing ope tion might have precipitated bone and soft-part necrosis and impairment of healing. Two years later, t function of the arm was as good as before the injury, and roentgenograms (Fig. 5-C) revealed compl fusion of grafts and fragments.

NON-UNION OF INFECTED FRACTURES

If a fracture becomes infected, either at operation or as a result of being compounde and fails to unite, the infection must be healed before an operation for non-union is co sidered. There is some danger of reactivating the infection, if the operation is perform through the site of the healed wound, with freeing of the fragment ends, removal of inte mediary and medullary callus, and fixation of the aligned fragments by an onlay bone gra anchored with screws. In order to minimize this risk, it has been the custom until recentl to delay operation for from six to eighteen months, depending on the extent and duratio of the lesion and the size of the bone involved; and also to excise scar tissue at a previo operation, if it is extensive. With the use of antibiotics, especially penicillin, it has bee possible to shorten this period somewhat.

When the fragments are in acceptable position, the simple type of onlay procedure, her described, has been employed, with avoidance of the old field of infection during the intr duction of the graft. The incision is made through healthy skin as far away from the sca as possible, and the soft parts and periosteum are reflected from the bone on the side oppo site the scar. If bony prominences are present, they are leveled off; the intermediary callu is never disturbed. The graft is introduced into the pocket, and over it the soft parts ar tightly sutured. By avoidance of the field of infection that has healed most recently an with the intermediary callus left undisturbed, the likelihood of infection is reduced to minimum; thus it was possible, even before the days of antibiotics, to perform the opera tion at a relatively early date, with a low incidence of infection and a high incidence o bony union, thereby saving the patient many months of disability. Depending upon the case, from one to four months should elapse after healing, before the operation is performed

Case 6. W. L., a male, aged sixty, fractured both bones of the right leg fifteen months before admission. The tibial fracture was compound and infected, and an open wound persisted on the medial side for thirteen and one-half months. The scar was elliptical, measuring one by four centimeters, and was well healed. Motion was present at the fracture site in the tibia. Roentgenograms (Fig. 6-A) revealed non-union of the fracture of the tibia and union of the fracture of the fibula. At operation, six weeks after wound healing, a whole-thickness graft, nine centimeters long by two centimeters wide, was removed from the upper fragment of the tibia, and the wound was closed. A second incision was made, lateral to the tibial crest at the fracture level and three centimeters away from the scar. The periosteum was reflected from the lateral aspect of the tibia; the protruding callus was chiseled off; the graft was inserted on edge, without removing intermediary callus; and the wound was sutured. No antibiotics were given, and the postoperative course was uneventful. When the cast was removed, ten weeks later, the wounds had healed *per primam*, there was bony callus between fragments and graft, and some ossification of the intermediary callus (Fig. 6-B). Walking was resumed soon afterwards; Figure 6-C shows the consolidation thirteen months after operation.

Case 7. J. G., a male, aged forty-three, was admitted on October 9, 1939, eight months after the fracture of both bones of the right leg, at the mid-shaft. The tibial fracture was compound, and was plated soon after injury. The wound became infected, and the plate was later removed, which left necrotic bone exposed where the plate had come in contact with cortex. On admission, the wound was still gaping and discharging pus. Roentgenograms revealed non-union of the fracture of the tibia and irregularity of the cortex on the anterior aspect, which had been produced by screw holes and bone absorption (Fig. 7-A). At operation, a strip of incompletely sequestrated necrotic cortex, from 5 to 7.5 centimeters long, was chiseled from each fragment, where the bone plate had been anchored. The wound granulated favorably. Five weeks later, the skin was undermined and sutured. The wound remained free from infection and three weeks later was completely healed. Two months afterward, roentgenograms revealed the extensive defects in the fragment ends, created by the fracture of the tibia and the excision. The fracture was still ununited (Fig. 7-B). Three and one-half months after operation, and six weeks after healing, a heavy graft, 12.5 centimeters long, was removed from the other tibia, and, through a posteromedial incision, the posterior surface of the fragments of the tibia at the fracture level were denuded of periosteum and callus. The graft was inserted into the bed, and the wound

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 1. Non-union of mandible of five months' duration.
Fig. 1-B: Four months after simple onlay bone graft.

showed that it was possible to obtain bony union and a good functional result without adherence to these teachings. The fracture in a twenty-two-year old woman (Case 1) was of five months' standing, and had been infected from communication with the mouth, but the wound had been healed for two and one-half months. A roentgenogram (Fig. 1-A) showed the fragments were well aligned, but with no sign of ossification of the intermediary callus. To have denuded the fragment ends and cleaned out the intermediary callus would have opened a wound in the mouth and invited reinfection, and to have fixed the graft to the fragments across the fracture site by screws or ties would have necessitated a relatively long and disfiguring skin incision. The procedure employed was as follows: A short incision was made on the under surface, and the periosteum was separated from the medial side of the fragment ends sufficiently to permit the onlay of an iliac graft, measuring approximately 4 by 1.5 by 0.5 centimeters. The intermediary callus was left in place, and the graft was held in position by suturing the overlying periosteum and soft parts tightly over it. The upper and lower teeth were held together with wires for two months. There was primary wound healing and, when the wires had been removed, the fracture was found to be united. Figure 1-B shows the degree of ossification of the intermediary callus and the fusion of the graft with the fragments, four months after operation.

Since the operation was short and simple, and the fracture united promptly, it was decided to apply these principles in similar cases of non-union in other bones. In fractures that have not been the seat of infection, the following general procedure is employed: The bone is exposed, and the periosteum is reflected only from the site to which the transplanted bone is to be applied. The remaining periosteum and callus hold the fragment ends together. If the denuded surface is level, no bone is removed; but it is usually uneven, and any protruding bone is chiseled off, in order to create a satisfactory bed for the graft or grafts. Usually the fibrous intermediary callus is left in place, but in some cases, part or all of it has been removed, with equally satisfactory results. As bony union between fragments and graft is established, the intermediary callus, which was laid down originally by osteogenic cells, reverts to a healthier state, under protection from trauma, and ossifies; or, if a pseudarthrosis is present, the cavity fills with callus which ossifies as motion is abolished. Angulation has occasionally been corrected, and sometimes this step has been facilitated by the removal of part of the intermediary callus. The fracture site is bridged by a broad, strong, whole-thickness, onlay graft or by two somewhat narrower, whole-thickness grafts. Cancellous bone is usually applied to the exposed fracture line on both sides of the graft.

between the two cortical grafts. None of the intermediary callus was removed. A plaster spica dressing was then applied, which was left on for three months. When the spica had been removed, there was no motion at the fracture site, and roentgenograms (Fig. 8-C) revealed signs of union between the grafts and fragments and partial filling in by bone along the old fracture line. A caliper splint was worn for three months, and weight was borne on the limb after the fourth month. Union progressed rapidly, and all of the intermediary callus could be seen as spongy bone in six months. Now, eleven months after operation, the callus is more dense, the limb is being actively used, and 75 degrees of motion has been established in the knee (Fig. 8-D).

This good functional result and the absence of wound infection justify the decision not to break down the fracture at operation, in order to correct the considerable degree of displacement of fragments.

DISCUSSION

Delagénière demonstrated that only osteoperiosteal grafts, without anchorage to fragments, should be used for the successful treatment of non-union; however, the operative trauma was extensive, since in all cases the fracture was broken down, the callus was removed, and the fragment ends were denuded in their entire circumference.

Harkins and the author analyzed the results in a series of thirty-nine patients, operated upon by the simple onlay method. These cases comprised 42 per cent. of the ununited fractures of the shaft operated upon during an eight-year period. Satisfactory results with bony union were obtained in thirty-eight cases. Since then, the author has had further experience with forty-nine cases. The distribution of the fractures according to the bone involved was as follows:

Tibia	22	Femur	3	Metatarsal	3
Humerus	7	Pelvis	3	Ulna	2
Mandible	5	Radius	3	Fibula	1

Bony union was obtained with one operation in forty-six of the forty-nine cases. One failure occurred in a three-year-old child with congenital pseudarthrosis of the tibia. The two other failures concerned fractures of the body of the mandible. One resulted from unequal distribution of the graft; two-thirds of this graft was in contact and united with the posterior fragment, and one-third was in contact, but failed to unite, with the anterior fragment, which was poorly immobilized because of so few teeth in the mandible. The other failure was due to infection of the graft as a result of a small opening into the mouth, which was not detected until the end of the operation. The graft was later removed, and the infection was allowed to heal. A similar operation, performed six months later, healed *per primam* and resulted in union of the fracture. This was the only instance of infection and loss of the graft in the entire series.

Infection occurred in thirteen of the cases as a result either of the initial compound fracture or of a previous operation, but all were healed before the operation for the non-union was performed. Six of these patients, five with fracture of the tibia and one with fracture of the femur, were operated upon between one and four months after wound healing, the graft being applied away from the site of previous draining except in the case of the femur. In all of these cases, healing occurred without infection. The other seven patients were operated upon six or more months after healing. There was primary wound healing and union of the fracture in every case except the mandibular fracture previously mentioned.

The rationale of the simple onlay-graft procedure is based on the following: The bone graft, whether in one or more pieces, is relatively strong. It bridges the fracture, splints the fragments, and contains osteogenic cells which survive along its periosteal and endosteal surfaces. Stripping of periosteum and other soft parts attached to one side of the bone, chiseling off prominences to create a level bed, and accurate application of the graft to the fragments set up osteogenesis from both shaft and graft. This results in the throwing out of callus, which ossifies and establishes bony union between the fragments and the graft.

The periosteum and soft parts are then reflected and tightly sutured over the transplanted bone. They hold the graft firmly against the shaft and prevent its displacement.

The length of the graft varies according to the fracture and the length of the bone involved. Grafts used for fractures of the mid-shaft of the long bones are usually from 7.5 to 12.5 centimeters long; while those for the end of the shaft are from 5.0 to 7.5 centimeters long, since short grafts fit better there and are easily held in place by the sutured soft parts. The grafts serve, to some extent, as internal-fixation splints. Plaster fixation is carried out for from two to three months, depending on the location of the fracture and the size of the bone; union is nearly always present at the end of that time. The results of such treatment are illustrated by the following cases:

Case 2. F. T., a female, aged thirty-three, had a simple fracture at the middle third of both bones of the left leg, of one year's duration, with union of the fibula and non-union of the tibia (Fig. 2-A). At the operation, an incision was made over the tibia, extending downward 22.5 centimeters from the tubercle. A whole-thickness graft, about 10 centimeters long by 1.5 to 2 centimeters wide, was cut from the upper fragment. The periosteum was then reflected from the medial side of the fragments at the fracture level, and the protruding cortex of the lower fragment was chiseled off to create a level surface. The graft was then inserted into the pocket, with its mid-portion at the fracture level and its periosteum external. Intermediary callus was not disturbed. Cancellous bone was applied anteriorly along the fracture line. The wound was closed tightly, and a cast was applied up to the mid-thigh, with the knee slightly flexed. On removal of the cast at the end of twelve weeks, the fractuie was solidly united, and roentgenograms (Fig. 2-B) revealed evidences of repair, including ossification of the intermediary callus. Walking was rapidly resumed, and roentgenograms one year after operation (Fig. 2-C) showed dense ossification of the intermediary callus and fusion of the graft with the fragments.

Case 3. T. W., a male, aged thirty, had a condition in which short grafts could be used to bridge a fracture of the end of the shaft. The fracture of the lower ends of the tibia and the fibula was of six months' standing, and there was comminution and non-union of the tibia (Fig. 3-A). Through a medial incision, the perios-

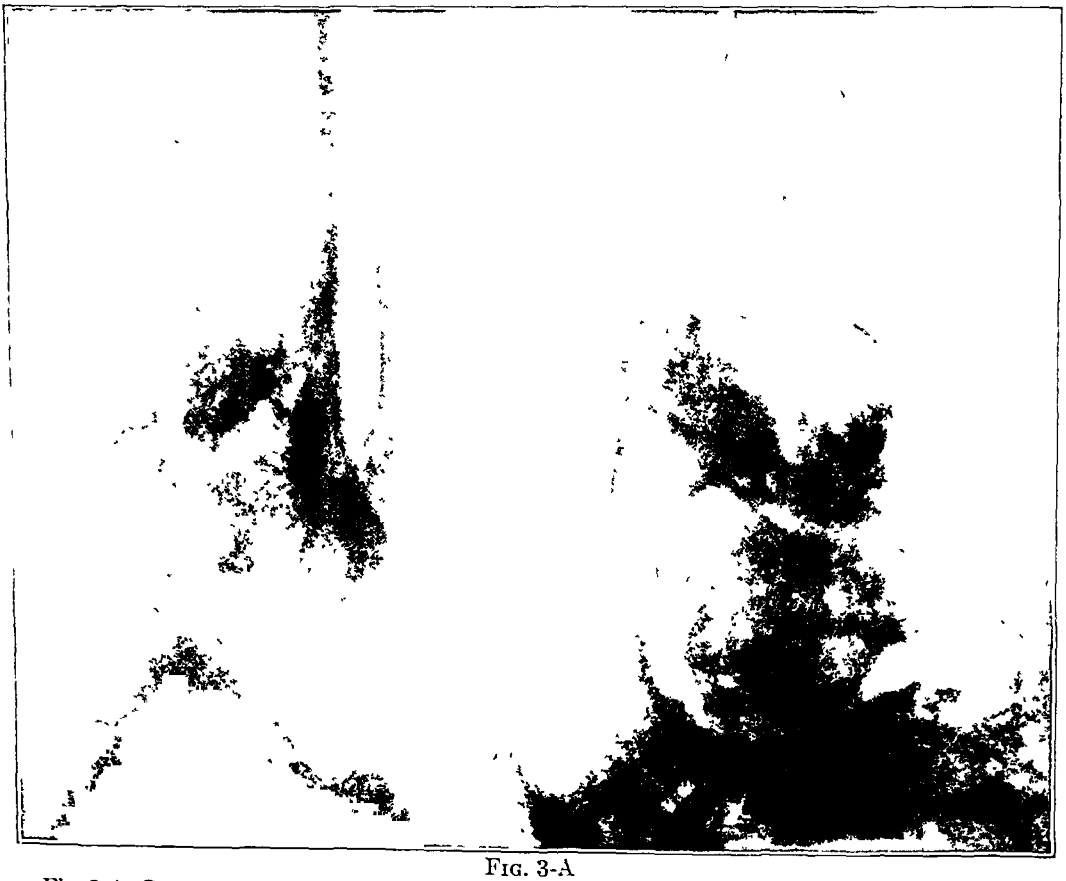

FIG. 3-A

Fig. 3-A: Case 3. Fractures of six months' standing. Comminution and non-union of the tibia are evident.

fracture is of the tibia and the degree of lateral displacement is great, warranting reduction, a modified Hoglund sliding-bone-graft operation is usually performed, with an onlay graft applied to ensure union, as well as the intramedullary graft for maintenance of position. This obviates the use of screws for fixation.

SUMMARY AND CONCLUSIONS

1. Ununited fractures of the shaft in which the fragments are in acceptable position have been treated by the application of one or two large bone grafts to a denuded level surface of the cortex across the fracture site, without fixation of graft to fragments with screws or ties, and usually without removal of the fibrous intermediary callus.

2. The grafted bone is held in position by the periosteum and soft parts sutured tightly over it; the fragments are adequately fixed by the remaining callus and attached periosteum, and by the plaster dressing.

3. The graft becomes solidly attached to the fragments, the intermediary callus ossifies, and bony union is established in a high proportion of cases, with a low incidence of infection. There has been no instance of fracture of the graft.

4. If there has been infection of the fracture which has already healed, it is possible to use this technique relatively soon after healing by placing the incision in healthy tissue away from the scar and applying the graft across the fracture line on the opposite side of the shaft. In this way the period of disability may be shortened by several weeks or months.

5. The results of the operation demonstrate the falsity of the teaching that, in order to obtain bony union of this type of fracture, it is necessary to remove the intermediary and medullary callus and to fix rigidly the graft to the fragments.

6. The operation is short, simple, and suitable for a majority of ununited fractures of the shaft. By this operation, the use of screws, plates, and wire is largely avoided.

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teum and callus were reflected from about half of the circumference of the fragments, and the intermediary callus was gouged and curetted out. The fibula was then osteotomized through a lateral incision, and the angulation was corrected by displacing the ankle backwards. Two short grafts, taken from the upper end of the shaft, were laid across the tibial fracture, one anteriorly and one posteriorly, and the soft parts were sutured over them. Twelve weeks later, when the plaster dressing had been removed, there was early bony union (Fig. 3-B). Figure 3-C shows the consolidation ten and three-quarters months after operation.

Case 4. W. W., a male, aged twenty-two, had a fracture of the mid-shaft of the left humerus, which was treated elsewhere the day after injury by open reduction and fixation with a wire, a metal plate, and screws. Non-union followed, and the plate and fragments became angulated. Figure 4-A shows the condition when first seen, five months after the injury. At operation through the old anterolateral incision, the underlying side of the bone was uncovered, and the screws, plate, and wire were removed. The intermediary callus was fibrous, and without removing it, the angulation was easily corrected. A bone graft 12.5 centimeters long, taken from the tibia, was laid across the fracture line in the bed vacated by the plate, and the soft parts were sutured tightly over it. The graft served well as an internal-fixation splint. A body cast, including the left upper extremity, was then applied. When it was removed twelve weeks later, the fracture was united, and roentgenograms, taken four months after operation (Fig. 4-B) revealed ossification of the intermediary callus and bony fusion of the graft with the fragments. One and one-half years later the functional result was excellent.

Case 5. E. T., a female, aged forty-four, had an intermuscular round-cell sarcoma of the lateral aspect of the right upper arm, extending to the elbow. It was treated by heavy irradiation and excision, which included a long segment of the radial nerve. There was irradiation damage to the region, but freedom from recurrence of the tumor. Twenty-three years later, the patient fell and injured the atrophic bones below the elbow. Six months later she appeared at the Clinic, with freely mobile ununited fractures of both bones of the forearm, as shown in Figure 5-A. At operation, a posterior incision was made, and the soft parts were reflected from the back of both bones at the fracture site. A tibial onlay graft was applied to both bones, without removal of

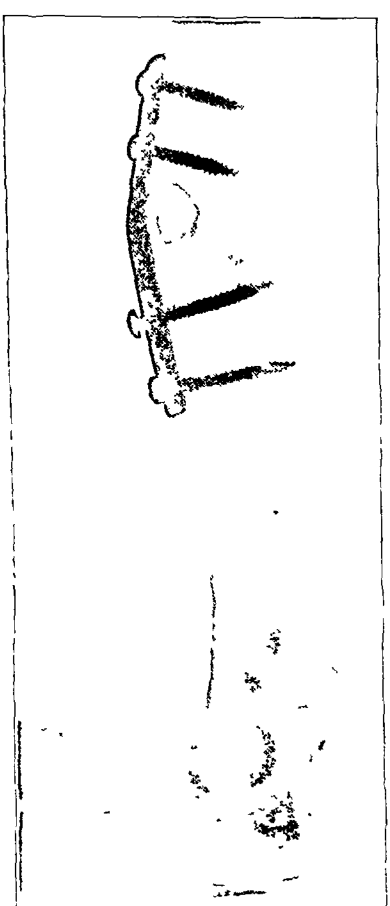

Fig. 4-A

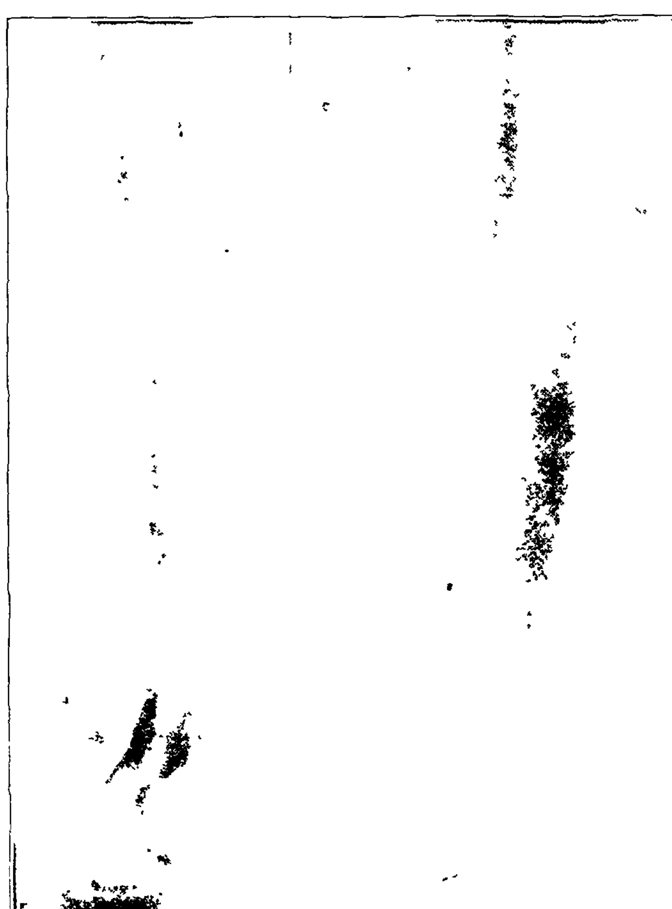

Fig 4-B

Fig. 4-A: Case 4. Non-union five months after early wiring and plating.
Fig. 4-B: Four months after simple onlay-graft operation.

followed until the time of healing of the graft. Consequently, the series represents a much more difficult problem in the restoration of bone continuity than would ordinarily be encountered in civilian practice.

During the first six months of the study, only eighteen bone-graft operations were performed, thirteen of these being of the sliding inlay or Albee type. Because of the increased healing period and the failure of union in five (38.5 per cent.), the procedure was changed to the massive onlay graft. Since that time, the inlay graft has been relegated more and more for the treatment of cases of delayed union in which an active healing process was evident.

The application of massive onlay grafts for the long bones proved to be the operation of choice in uncomplicated cases of non-union. The periosteum was carefully stripped from the bone ends to give a continuous sheet, and all fibrous tissue was removed from between the fracture fragments. The ends were freshened to allow good contact, prior to preparation of the bed for the reception of the graft. The medullary canal was opened and cleaned out with a curette to permit endosteal repair.

The graft, measuring seven inches in length and as wide as could be obtained without invading the tibial crest, was usually taken from the opposite tibia. Shorter grafts were used in the upper extremity; the width was determined by the size of the bone being repaired. In the preparation of the graft, all of the cancellous bone on the medullary surface was removed with a saw or chisel, and saved to pack around the fracture site. Additional bone chips were obtained from the upper end of the tibia or ilium, as indicated. The bed for the reception of the graft was prepared by the removal of at least two-thirds of the thickness of the cortex at its thinnest point, to give a flat surface.

Dual bone grafts were first used during 1943, when eight operations of this type were performed. Since that time, an increasing number of the dual-type operations have been performed,—partly because of the type of fracture being treated. However, as will be shown by this study, our indications for the use of the dual-type graft have changed considerably. The bone used for the dual graft was the same width as that for the onlay graft, whenever possible. The maximum graft obtainable from the tibia of the average adult is approximately eleven and one-half inches in length.

Ten cases were seen of fracture of the tibia from which the graft had been removed early in the series. The necessity of a properly fitted, molded leather cuff, to be incorporated in a double-bar, short leg brace prior to the resumption of weight-bearing, cannot be emphasized too strongly. This device effectively eliminated the serious complication of fracture of the donor tibia, which occurred frequently prior to the adoption of this simple precautionary measure.

The problem of closing the periosteum over the graft in those instances in which massive onlay grafts or dual bone grafts are used was solved satisfactorily by making one or more longitudinal slits through the periosteal cuff on the side opposite the graft. By so doing, a periosteal covering may be shifted forward to close over the graft, and the soft tissue may be sutured without tension.

Rigid fixation of the graft by machine-type screws not only is considered advisable, but is imperative if early motion is to be initiated. Many of the patients with uncomplicated bone grafts were being supported by a bivalved cast or by traction, and were receiving physiotherapy for mobilization of the adjacent joints by the sixth week after operation. Unfortunately, follow-up measurements on joint motion were not complete enough to be trustworthy. It was obvious, however, that a good deal of time was saved during the convalescent period; and, in many instances, the permanent disability was altered considerably, as compared to similar types of cases treated by other methods.

One of the authors (A. L. S.) has been using bone plates in conjunction with bone grafts since 1940. In this series, plates were utilized whenever strength and stability was needed, but never as a substitute for a graft. Plates were used in conjunction with three

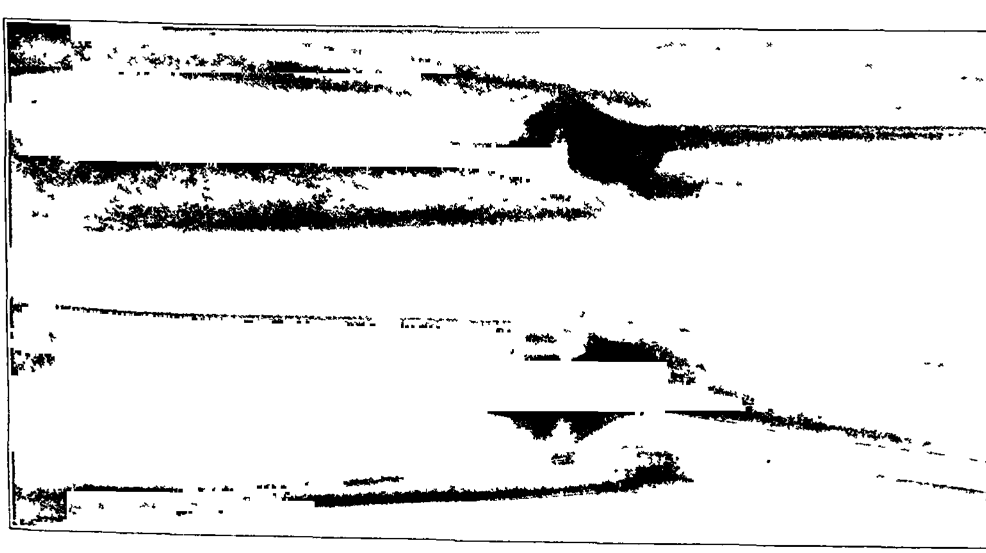

FIG. 6-A

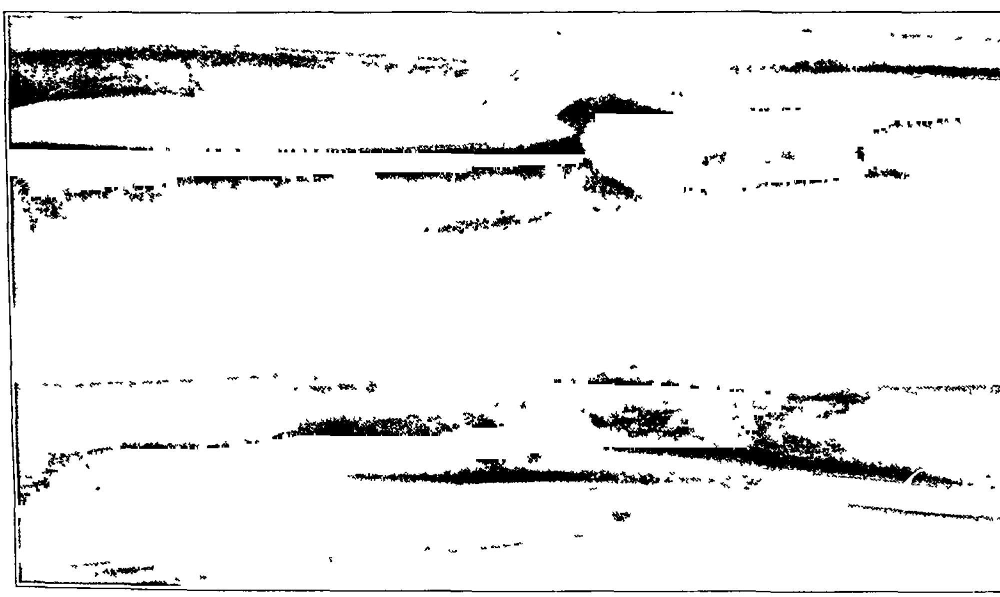

FIG. 6-B

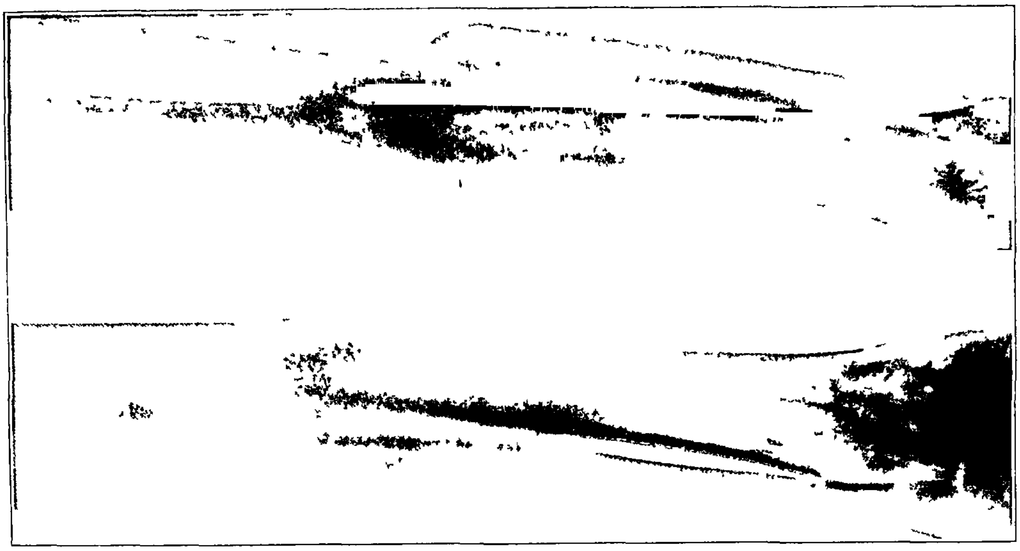

FIG. 6-C

Fig. 6-A: Case 6. Non-union of tibia of fifteen months' duration.
Fig. 6-B: Ten weeks after operation. Fig. 6-C: Thirteen months after operation.

TABLE III

AVERAGE HEALING TIME ACCORDING TO TYPE OF GRAFT AND BONE INVOLVED

Bone	Inlay		Onlay		Dual		Total	
	No. of Grafts	Average Healing Time (*Weeks*)	No. of Grafts	Average Healing Time (*Weeks*)	No. of Grafts	Average Healing Time (*Weeks*)	No. of Grafts	Average Healing Time (*Weeks*)
Clavicle	1	24	1	22	4	12	6	19
Humerus	4	31	6	15	39	16	49	17
Radius	4	21	18	18	27	17	49	16
Radius and ulna	0	0	11	17	0	0	11	17
Ulna	8	25	18	21	23	14	49	18
Femur	1	26	25	22	28	22	54	22
Tibia	16	24	42	22	42	24	100	23
Totals	34	27 *	121	20	163	19	318	20

* This figure is based upon the exact number of weeks required for healing in each case, rather than upon the average times given in this table.

inlay grafts, twenty-three onlay grafts, and twelve grafts of the dual type. These results have not been tabulated separately, because there was no appreciable difference in the healing time. No fractures occurred in this group of thirty-eight cases.

AVERAGE HEALING TIME OF BONE GRAFTS

Of the 358 cases with adequate follow-up (Table I), 39 (10.9 per cent.) had inlay grafts, 144 (40.2 per cent.) had onlay grafts, and 175 (48.9 per cent.) had dual-type grafts. The average healing time for the entire series of 318 grafts which were followed to union was twenty weeks (Table III). Inlay grafts, which were used under the most favorable circumstances to secure union, were the slowest to heal, averaging twenty-seven weeks; onlay grafts, used in the more favorable type of case, averaged twenty weeks; and the dual-type graft, which was used only in those instances in which slow union was anticipated by other methods, averaged nineteen weeks.

A study of Table III will show a difference in the average healing time for the weight-bearing and non-weight-bearing bones, as would be expected from the criteria set up in this study for the determination of union.

TABLE IV

AVERAGE HEALING TIME OF 318 BONE GRAFTS

Healing Time (*Weeks*)	Type of Graft			Total Grafts		Composite Analysis	
	Inlay	Onlay	Dual	No.	Per cent.	No.	Per cent.
Under 12	0	4	12	16	5.0	16	5.0
12 to 13	1	24	40	65	20.4	81	25.5
14 to 16	2	21	34	57	17.9	138	43.4
17 to 20	6	25	36	67	21.1	205	64.5
21 to 25	6	16	17	39	12.3	244	76.7
26 to 30	9	15	15	39	12.3	283	89.0
Over 30	10	16	9	35	11.0	318	100.0
Total number of cases	34	121	163	318	100.0	318	100.0
Average	27	20	19	20			

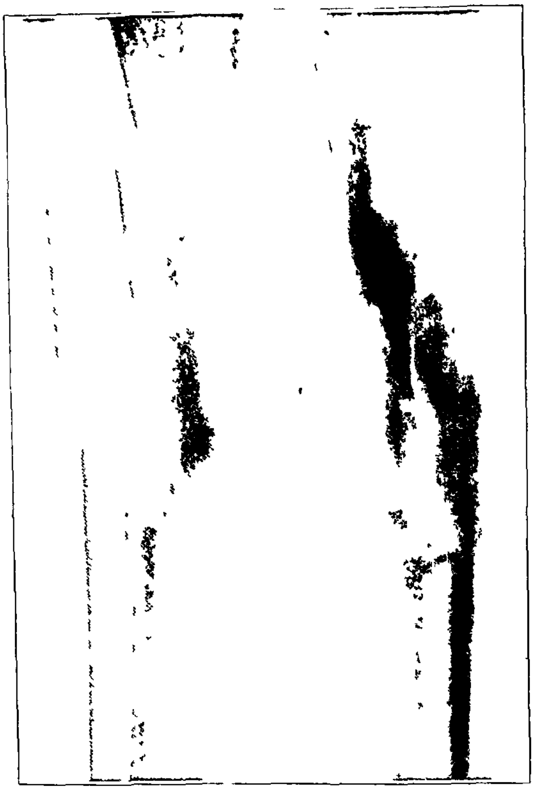

Fig. 7-A

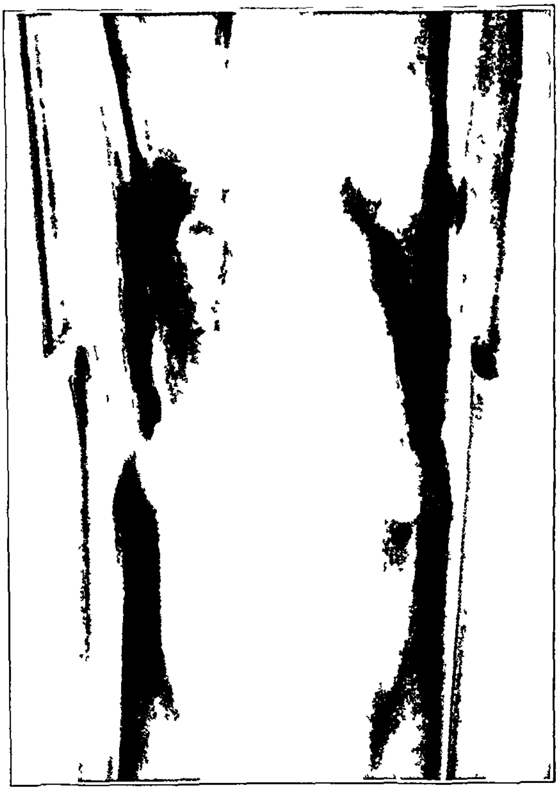

Fig. 7-B

Fig. 7-A: Case 7. Non-union, osteomyelitis, and dead bone eight months after injury and application of plate and screws to tibia.
Fig. 7-B: Three and one-half months after removal of dead bone and six weeks after healing of the secondarily sutured wound.

Fig. 7-C

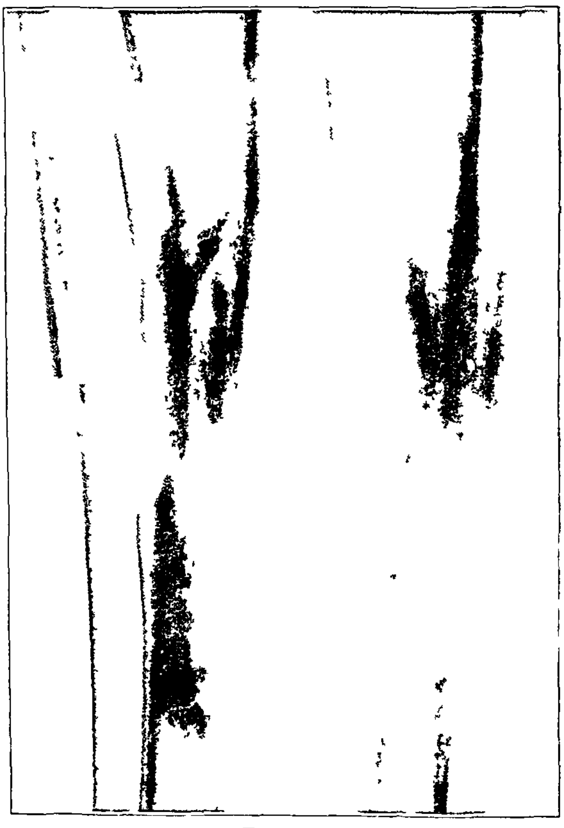

Fig. 7-D

Fig. 7-C: Three months after application of graft to posterior surface through posteromedial incision.
Fig. 7-D: Eight months after bone-grafting.

DELAYED UNION OF BONE GRAFTS

To record in detail the healing time of the various types of grafts in each of the long bones would require too much space, and would not disclose anything more of significance than would a composite analysis, as recorded in Table IV. This tabulation shows that 138 (43.4 per cent.) of the bone grafts had united by the end of the sixteenth week.

On the assumption that certain factors which tend to delay healing of the graft would be evident in those cases requiring seventeen or more weeks to unite, a detailed study was initiated. In some cases, more than one such factor was evident. Only the apparent primary cause of the delayed union in the remaining 180 cases (56.6 per cent.) is shown in Table V.

Local impairment of calcium metabolism accounted for the greatest number of cases of delayed union. Of the 180 cases requiring more than sixteen weeks to heal, forty (22.2 per cent.) presented severe decalcification of the ends of the bones, and thirty-two (17.8 per cent.) had sclerosis of one or both of the major fracture fragments at the time of the bone-graft operation. This group of seventy-two cases of delayed union had the following distribution: seven inlay grafts, which had healed in an average of twenty-seven weeks; twenty-five onlay grafts, which averaged 30.4 weeks for healing; and forty dual-type grafts, used in the cases with more pronounced local disturbance of calcium metabolism, which had an average healing time of only 22.5 weeks.

The third most common cause of delayed union of the graft occurred in cases in which the graft was used to bridge a defect. Without exception, inlay and onlay grafts were not satisfactory when used for this purpose; but, of the 112 dual-type bone grafts used to bridge defects up to five and one-half inches in length, only thirty (26.7 per cent.) failed to have union by the sixteenth week.

In seventeen (9.5 per cent.) of the cases of delayed union, no apparent cause was determined; eleven of these were of the inlay type.

Of the twenty-six infections without sequestration of the graft, thirteen grafts failed to unite by the end of sixteen weeks; but there was no case of non-union without other contributing factors.

Inasmuch as it was our practice to remove at least two-thirds of the thickness of the cortex in the preparation of the bed for the reception of the graft, only thirty-five cases with poor apposition of the graft were collected. Of these, there were thirteen cases of delayed union. The average healing time for the series, when compared with an unselected group of similar grafts of our own, was prolonged by 4.7 weeks.

Fracture of the graft occurred in twenty-three cases (Table II); of the nine which went on to union, all were slow to heal, averaging twenty-four weeks from the time of the fracture.

Poor choice of the type of operative procedure by the use of a poorly fixed onlay graft near a joint accounted for six delayed unions in ten cases. However, there were only four delayed unions in fifty-four of the dual-type operations, done for non-union near a joint.

NON-UNION OF GRAFTS

Failure of the bone graft to unite was encountered in forty (11.2 per cent.) of the cases (Table VI). Fracture of the graft occurred in twenty-three instances, and accounted for fourteen (35 per cent.) of the non-unions. The average time from the fracture of the graft to a subsequent attempt at repair was sixteen weeks.

Infection with sequestration of the graft accounted for twelve (30 per cent.) of the failures. Sclerosis of one or both fracture fragments was considered to be responsible for five failures (12.5 per cent.), and extensive decalcification of the bone ends accounted for an equal number. Poor choice of the type of operative procedure, with inadequate fixation of an onlay graft near a joint, accounted for one failure. Short grafts (less than three inches in length) were responsible for three other instances of non-union.

The undisturbed periosteum and peripheral callus of the rest of the circumference serve to hold the fragments together, as does also the intermediary callus when it is not removed. Consequently, displacement of fragments cannot take place. The graft is held so snugly against the fragments by the tightly sutured overlying periosteum and soft parts that it does not work out of place. At the same time, it does not remove the stimulus to fracture healing which is derived from impaction of the fragment ends by muscle pull; nor does the graft fracture, as sometimes happens when a graft is rigidly fixed to the fragments by screws. As union between graft and shaft progresses, the old intermediary callus, which is derived from osteogenic tissue, becomes increasingly protected from the trauma of motion and increasingly subjected to the functional stimulus derived from skeletal support. These forces convert the unhealthy callus into healthy callus, which then goes on to ossification. If pseudarthrosis is present, callus grows into and obliterates the false joint space, where it ossifies. The plaster dressing fixes the fragments for from two to three months and assures maintenance of position.

There has been no opportunity for microscopic examination of the callus during the period of transformation into bone.

There is much additional evidence that a fibrous union or pseudarthrosis may be made to ossify, if the damaging effects of motion on the callus are removed and the reparative stimulus is restored by a bridge of bone. If an ununited fracture of the carpal navicular is treated by the insertion of a bone peg through the interior of the bone across the fracture line, the fracture unites; and what is left of the fibrous intermediary callus, after the peg hole has been drilled, ossifies. Murray has recently reported 100 cases with ninety-six successful results.

Ununited intracapsular fractures of the neck of the femur, with the fragments in good position, have been observed to unite after the introduction of one or two intramedullary bone pegs, without removal of the intermediary callus. The same may happen, if the bone pegs are combined with threaded wires. In a well-performed Putti-McMurray operation for non-union of the neck of the femur, the medial portion of the medially displaced cut end of the distal fragment usually overlaps the under side of the neck, crossing the line of non-union in a manner similar to the short onlay graft employed in non-union of the end of the shaft in other locations. This overlapping and the placement of the fracture of the neck at rest by osteotomy are two important factors in bringing about union of the fracture.

An ununited fracture of the mid-shaft or subtrochanteric region of the femur with angulation of the fragments may be satisfactorily straightened without removal of the intermediary callus; but, because of the danger of recurrence of the angulation in the cast, it may be advisable to fix the onlay graft to the fragments with screws. In that event, we have found that, if the intermediary callus has been left alone, it will ossify promptly, as the graft and shaft unite; the patient may thereby be spared a more prolonged, traumatizing, and bloody operation.

As we have had added experience with this operation, the indications for the use of the simple onlay graft have been extended, until they now include the large majority of ununited fractures of the shaft of long bones. In considering the treatment of such cases, the first question raised is whether or not the result would be acceptable were the fracture united in its present position, or, if necessary, after simple correction of angulation. If the position of the fragments is satisfactory, the simple onlay-graft operation is performed. However, if marked displacement or overriding is present, it is usually best to break down the fracture and then fix the reduced fragments rigidly with an onlay-bone graft and screws, since displacement is likely to occur without fixation. Ununited fractures of both bones of the forearm, with angulation which restricts rotation, should be treated by breaking down the fracture line of one or both bones and fixing the fragments with an onlay graft and screws. If angulation is slight or absent, the simple onlay graft is indicated. In case the

TABLE VII

RESULTS OBTAINED WITH THE THREE TYPES OF GRAFT IN CONDITIONS TENDING TO RESULT IN DELAYED HEALING TIME *

Clinical Conditions	Inlay			Onlay			Dual			Totals		
	Total	Delayed Union	Failure of Union	Total	Delayed Union	Failure of Union	Total	Delayed Union	Failure of Union	Total	Delayed Union	Failure of Union
Bridging of bone defect	8	5	3	8	5	3	112	20	0	128	30	6
Non-union near a joint	4	2	2	16	6	4	54	4	0	74	12	6
Sclerosis of one or both fracture fragments	5	4	1	17	10	5	25	18	1	47	32	7
Severe decalcification of fracture fragments	4	3	1	19	15	4	26	22	1	49	40	6
Failure of previous bone graft, regardless of cause	0	0	0	10	6	4	22	9	0	32	15	4
Fracture of a graft	4	2	2	17	7	10	4	2	2	25	11	14
Postoperative infection without sequestration	2	1	1	12	5	0	12	7	0	26	13	1
Postoperative infection with sequestration	1	0	1	4	1	3	8	0	8	13	1	12
Short graft (three inches or less)	10	5	2	11	7	3	0	0	0	21	12	5
Poor apposition of graft	0	0	0	26	8	2	9	5	0	35	13	2

* This is a complete tabulation; more than one factor is evident in a number of cases, and the figures represent the total number involved.

BONE GRAFTS

An End-Result Study of the Healing Time *

BY LIEUTENANT COLONEL W. A. BISHOP, JR., MAJOR RICHARD C. STAUFFER, AND CAPTAIN ALVIN L. SWENSON

Medical Corps, Army of the United States

INTRODUCTION

During the past few years, much valuable experience has been gained and considerable progress has been made as a result of the large number of bone-graft operations done in military hospitals. However, the problem of securing early union in a fracture which failed to unite primarily is still far from being an easy one. Consequently, orthopaedic surgeons should not accept too readily the favorable reports which continue to appear in surgical journals. Too many of these articles on bone-graft surgery represent a survey of the literature, and would indicate that any type or modification of a previously described bone-graft operation had proved to be entirely satisfactory.

This follow-up study was initiated in an attempt to work out the indications for the use of the various types and modifications of bone-graft operations, as determined by their respective merits, with the healing time under various clinical conditions being used as a guide.

The survey represents the authors' experience with bone-graft operations at William Beaumont General (Army) Hospital from June 1942 to September 1946. During this period, 580 grafts of the long bones came under our observation; but, due to the nature of a military hospital in wartime, adequate follow-up data are available on only 358 (61.7 per cent.) of this group. Approximately two-thirds of these bone-graft operations were either done by the authors, or were carried out under their supervision or with their assistance. Most of the other cases were transferred to the authors' care during the convalescent period, for further observation and treatment. The composite study appeared more representative and, therefore, more significant as a statistical report. Consequently, no attempt has been made to separate the two groups, because it is the authors' intention to present the problems encountered in bone-graft surgery rather than to report a personal series.

The results obtained by the various types of procedures employed are both interesting and significant. This report is confined to a study of the healing time of the fracture following a bone-graft operation; and was determined by the clinical condition and by the roentgenographic appearance of the fracture line and of the graft. It represents the time interval in weeks up to the point at which sufficient union had taken place so that it was considered safe to allow restricted use of the upper extremity, or full weight-bearing, usually supported by a brace, on the lower extremity.

Before the types of grafts used and the reasons therefor are discussed, it is significant to point out that the majority of these ununited fractures represented the sequelae of serious gunshot wounds of the extremities. In many, there was loss of skin and underlying soft tissue, and often of bone substance. All too often, the comminuted bone fragments were debrided in the early treatment of the wound, resulting in a defect and non-union. Due to the extensive nature of these wounds, considerable scar tissue invariably formed about the fracture ends, resulting in the many unfavorable factors involved in the healing process, associated with diminution of the available blood supply. Full-thickness skin grafts of the pedicle type were necessary in 76 (21.2 per cent.) of the cases which were

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1947.

10. Plates should be used in conjunction with bone grafts when additional stability is needed, but should never be used as a substitute for the proper type of graft.

NOTE: The contents of this paper do not necessarily represent the policy of the U. S. Army Medical Corps. The ideas expressed are those of the authors, all of whom have resumed civilian practice.

DISCUSSION

MAJOR GENERAL NORMAN T. KIRK, WASHINGTON, D. C.: I am delighted to have the opportunity to discuss these excellent papers on the various types of bone grafts in the treatment of non-union. Different approaches as to procedure and means for the use of internal fixation have been presented, as well as an excellent follow-up report of a large number of bone grafts. End results in regard to failure of union and time of healing required, based on the method of graft used as well as on the various bones involved, have been shown.

Dr. Phemister prefers the onlay type of graft with no fixation except soft-tissue closure; and, in the beginning of his paper, he states that this type of procedure is one for the treatment of selected types of ununited fractures. The results he shows are excellent. Possibly the type of case for this method is limited to those shown by the author, as they would appear not to require firm fixation of the graft to assure stability of the fragments after the plaster had been applied. It is questioned whether this method would succeed when there was marked loss of substance or loss of stability at the fracture line, preceding the operative procedure. I am sure there is complete agreement with Dr. Phemister that, with decrease in the stripping of soft tissues from the fragment ends and in the extent of the operative procedure, there will be less disturbance to the circulation to the part, less shock, fewer deaths, and less chance of infection. It is believed that a graft to the external surface of the tibia, under a covering muscle, as he has applied it, is a superior method to that of placing the graft on the inner surface, when consideration is given to blood supply to the graft from the soft tissue covering it. However, I cannot agree with Dr. Phemister—and war experience clearly demonstrated this—that a graft should be done at any time in any extremity when a sinus is present, connected with the original fracture, or when there is scar in the extremity that might break down because of an operative procedure in that extremity.

Dr. Bishop and his associates report their observations with 580 bone grafts, which came under their care in one Army General Hospital in the war years of 1942 to 1946. Their statistical analysis gives a follow-up on 358 of these cases and is a most interesting one, showing the healing time, the failures, and other statistical data, as applied under different conditions to different bones by the presently accepted methods of bone-grafting. This represents a great many bone grafts for the correction of non-union and lost substance, following fractures in long bones, to be observed by any group in a four-year period.

These surgeons feel that rigid fixation of the graft to its bed by metal screws is essential, particularly if early motion is to be instituted,—beginning at the end of six weeks, on an average. One of the group supplemented the graft with a steel plate and screws in thirty-eight of these cases, to add strength and stability. There was no apparent difference in the healing time in these cases, and there were no fractures in this group.

The sliding inlay type, used by this group at first, was soon discarded, because it was felt that union did not progress so rapidly as might be expected by the use of the massive onlay type of graft. Thus the method devised by Albee was discarded; and the massive onlay type, used and publicized by Campbell, was adopted. There were thirty-nine cases in which the inlay-type graft was used, with five failures, or a percentage failure of 12.8. In doing an onlay-type graft, a massive graft was cut and about two-thirds of the thickness of the cortical shaft forming the graft bed was removed. This placed the graft in contact with the medullary blood supply of the involved bone ends. This is a modification of the Campbell method, as Campbell removed only sufficient bone to make a flat bed to receive the graft. Phemister does not recommend the removal of as much bone as this in the formation of a graft bed. Peterson reported several cases of bone grafts to the femur before this Society in 1943, using this method of having the graft bed in contact with the medullary blood supply. He believed that this hastened union. In this I agree. Johnson pointed out, in experiments on dogs some years ago, that medullary blood supply was essential for union.

In this series, 144 cases are reported in which this method was used, with twenty-three failures, or a failure of 16 per cent. This method involves a more extensive surgical procedure than that advocated by Phemister, and interferes with circulation to the bone at least to 50 per cent. of its circumference.

Dual grafts, developed by Boyd, were first used by this group in 1943; and apparently soon became the most popular method to meet the situation then confronting these surgeons in caring for non-union. It was the method of choice of these authors to bridge defects; to correct non-union adjacent to joints; in atrophic and sclerotic bone; and when a previous graft had failed. In this series 175 cases are reported, with twelve failures, or a failure of 7 per cent. Failure to obtain union, then, when the type of graft used was the only factor considered, occurred more often in the massive than in the dual-type graft. Likewise, the adjudged healing time averaged nineteen weeks with the dual graft, twenty weeks with the onlay graft, and twenty-seven weeks with the inlay graft, a general average of twenty weeks.

TABLE I

ANALYSIS OF TOTAL NUMBER OF GRAFTS

Bone Involved	Inlay				Onlay				Dual				Totals			
	Total	Adequate Follow-up	Union	Non-Union	Total	Adequate Follow-up	Union	Non-Union	Total	Adequate Follow-up	Union	Non-Union	Total	Adequate Follow-up	Union	Non-Union
Clavicle	3	3	1	2	4	2	1	1	6	4	4	0	13	9	6	3
Humerus	5	4	4	0	17	9	6	3	59	45	39	6	81	58	49	9
Radius	6	4	4	0	40	19	18	1	36	29	27	2	82	52	49	3
Radius and ulna	0	0	0	0	24	11	11	0	0	0	0	0	24	11	11	0
Ulna	14	9	8	1	38	21	18	3	31	23	23	0	83	53	49	4
Femur	2	2	1	1	60	33	25	8	43	30	28	2	105	65	54	11
Tibia	25	17	16	1	107	49	42	7	60	44	42	2	192	110	100	10
Totals	55	39	34	5	290	144	121	23	235	175	163	12	580	358	318	40

TABLE II

END RESULTS IN TWENTY-THREE FRACTURES OF THE GRAFT

	Humerus			Ulna			Femur			Tibia			Totals			
	Inlay	Onlay	Dual	Inlay	Onlay	Dual	Inlay	Onlay	Dual	Inlay	Onlay	Dual	Inlay	Onlay	Dual	Total
Total number	1	5	1	1	2	0	0	8	2	1	2	0	3	17	3	23
Cases of non-union	0	4	1	1	2	0	0	3	1	1	1	0	2	10	2	14
Average time from fracture to re-graft (*weeks*)		15	9	14	15			19	28	14	16		14	16	22	16
Type of re-graft	0	2	3	0	1	2	0	1	3	0	1	1	0	5	9	14
Average healing time of re-graft (*weeks*)		24	16		30	15		22	18		28	19		26	17	20
Fractured grafts with eventual union	1	1	0	0	0	0	0	5	1	0	1	0	1	7	1	9
Average time from graft fracture to union (*weeks*)	26	20			24	21		24	21		30		26	24	21	24

Probably we shall have to change our opinion as a result of the experience in these papers, and use the dual rather than the onlay graft for loss of substance and in meeting the problem presented by sclerotic and atrophic bone. I have had no personal experience with the dual-type graft. I still feel, however, that all scar tissue between bone ends should be removed before a bone graft is applied, unless that scar tissue is needed for stability, in that it limits the blood supply to the graft and to the fragments.

I am sure that the papers presented will give all of us new thought as to types of grafts to be employed when we are confronted with non-union and lost substance in long bones.

Dr. George O. Eaton, Baltimore, Maryland: Dr. Phemister has presented a very simple method for use in cases which are in reality very simple bone-grafting problems, in that alignment at the site of non-union was satisfactory and needed no correction. This implies minimum operative trauma and, consequently, minimum disturbance of the local circulation. The cases selected for this type of procedure are only 42 per cent. of the total number needing bone-graft procedures. In the ten cases which he presents today and the eighty-eight cases which he refers to, the percentage of successful operations is almost 100. These results are testimony to the efficiency of the local circulation and to the relative lack of circulatory embarrassment due to operative trauma. I doubt very much if the percentage of unions would have been reduced by screw fixation of the graft to the host. I should like to ask Dr. Phemister what method he uses for the more difficult bone-grafting problems.

Dr. Bishop and his colleagues have given us their results and conclusions, based on a follow-up study of 358 cases in which various types of bone-graft operations have been done by surgeons of variable ability. One-third of their cases were done elsewhere, and were observed by the authors during convalescence. I believe that their conclusions, based on so large a series, should form a reliable guide in estimating the relative chance of a successful bone-graft operation by the average surgeon. It is unfortunate that the types of fracture could not have been classified as simple and compound. F.C.C. is a well-known term to many of us, meaning fracture, compound and comminuted; the fracture was usually due to injury by high-velocity missiles. This type of fracture was seen chiefly in combat troops in battle. Combat troops at rest or in training and all other troops usually sustain simple rather than compound fractures. F.C.C. carries with it a variable, but often very extensive, degree of soft-tissue injury, including impairment of local circulation. The factors of damage to circulation and prompt and efficient immobilization determine, more than any other factors, the rate of healing of fresh fractures and of bone grafts. We have prompt union, delayed union, and non-union of bone grafts, just as we do of fresh fractures; and the factors which determine the rate of healing are basically the same in both instances. A most important prerequisite to successful bone-grafting, particularly on subcutaneous bones, is the removal of scar tissue overlying the bone and its replacement by a thick, healthy pedicle graft. Many of us have seen union take place while we were waiting for the pedicle graft to mature sufficiently to operate through it. Complete and sudden disruption of circulation in bone leads to aseptic necrosis; partial reduction of blood supply to bone results in atrophy and demineralization. Greenberg and Mohamed have produced delayed union of fractures experimentally in rats by partially ligating the femoral arteries. Activity and use of a limb with an ununited fracture, but protected by a suitable brace, is often indicated preparatory to grafting, so as to rejuvenate a sluggish circulation. In Dr. Bishop's series, the highest percentage of failures occurred where there was marked decalcification of the fracture fragments.

Dr. Bishop's paper is a very valuable contribution. Not many of us will be able to report follow-up studies on 358 cases of bone grafts, particularly in the types of fractures seen in war surgery. He is to be congratulated on his foresight in recognizing the value of such a study and in successfully carrying it out under the difficulties presented by military practice in wartime.

Dr. D. B. Phemister (closing): With reference to the preparation of the bed for the graft, some of the speakers emphasized the advisability of cutting away a good deal of the peripheral portion of the fragments. Personally, I strip the periosteum thoroughly, leaving a well-denuded surface; but I do not remove any more cortex than I have to, in order to create a level bed for the graft. The stimulus of removing the periosteum is enough to incite callus formation from the cortex, and the graft itself also forms callus. It is the combination of the callus from the two which brings about union between the fragments and the graft.

The advisability of using internal fixation in order to obtain early motion was mentioned. I believe that I have stretched a point in prolonging the immobilization during the period of healing of fractures operated upon by this method, because, in two patients who were confined to bed as a result of additional injuries, I did the operation without applying a cast at all, and the fragments united just as promptly as in the cases in which casts had been applied. If some of the patients with leg fractures were allowed to go on crutches without cast fixation, they would probably obtain bony union, and joint motion could be restored at an early date. However, I do not advise this as a routine procedure.

Dr. Eaton asked what technique I favor in case it is necessary to break down the fracture line and realign the fragments. I usually use the same technique which is generally used,—namely, the application of

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TABLE V

ANALYSIS OF 180 CASES OF DELAYED UNION OF BONE GRAFTS ACCORDING TO APPARENT CAUSE

Cause of Delayed Union	Inlay 17 to 20 Weeks	Inlay 21 to 25 Weeks	Inlay 26 to 30 Weeks	Inlay Over 30 Weeks	Inlay Total	Onlay 17 to 20 Weeks	Onlay 21 to 25 Weeks	Onlay 26 to 30 Weeks	Onlay Over 30 Weeks	Onlay Total	Dual 17 to 20 Weeks	Dual 21 to 25 Weeks	Dual 26 to 30 Weeks	Dual Over 30 Weeks	Dual Total	Total No.	Total Per cent.
Severe decalcification of fracture fragments	1	0	1	1	3	5	1	2	7	15	12	5	2	3	22	40	22.2
Sclerosis of one or both fracture fragments	1	0	3	0	4	0	1	4	5	10	10	3	5	0	18	32	17.8
Bridging bone defect	1	2	2	0	5	0	3	2	0	5	8	6	1	5	20	30	16.7
Cause undetermined	2	2	2	5	11	3	0	0	0	3	1	1	1	0	3	17	9.5
Postoperative infection without sequestration	0	1	0	0	1	2	2	0	1	5	3	1	3	0	7	13	7.2
Poor apposition of graft	0	0	0	0	0	5	1	1	1	8	2	1	2	0	5	13	7.2
Short graft (three inches or less)	0	1	1	3	5	3	1	1	2	7	0	0	0	0	0	12	6.7
Fracture of graft	0	0	1	1	2	0	0	2	3	5	0	0	1	1	2	9	5.0
Second or subsequent graft following failure	0	0	0	0	0	1	1	2	2	6	1	1	0	0	2	8	4.4
Poor fixation near joint	0	0	0	0	0	1	1	2	2	6	0	0	0	0	0	6	3.3
Total with delayed union	5	6	10	10	31	20	11	16	23	70	37	18	15	9	79	180	100.0
Total with union					34					121					163	318	
Percentage with delayed union	14.8	17.6	29.4	29.4	91.2	16.5	9.1	13.2	19.0	57.8	22.7	11.0	9.2	5.5	48.4	56.6	

TABLE I

ESTIMATED AMOUNTS OF CHONDROITIN SULPHATE AND ALKALINE PHOSPHATASE IN THE INTERCELLULAR MATRIX OF CARTILAGE, OSSIFYING CARTILAGE, AND BONE

Developmental Stage and Type of Ossification	Type of Tissue	Approximate Amount of Chondroitin Sulphate According to the Present Investigations	Approximate Amount of Alkaline Phosphatase According to Other Authors
Embryonic	General mesoderm	None (or slight)	Large [5, 9]
	Precartilage	Just demonstrable	Large [5, 9]
	Protochondrium	Large, *increasing*	Rapid decrease [9]
	Perichondrium	None (or moderate)	Moderate (varying) [5, 9]
Endochondral Ossification	"Hypertrophic" cartilage (vesicular layer)	Large, *decreasing*	Increasing [9]
	Calcifying cartilage	None	Large [9]
	Embryonic bone marrow and osteoblasts	None	Large [9]
	Newly formed endochondral bone	None	Large [9]
Perichondrial Ossification	Diaphyseal perichondrium at beginning of ossification	None	Large [9]
	Periosteal osteoblasts	None	Large [9]
	Newly formed perichondrial bone	None	Large [9]
Intramembranous Ossification	Preosteal osteoid	Moderate	
	Osteoblasts	None	Probably large
	Newly formed bone	None	
Adult	Cartilage	Large	Absent [1, 5, 9]
	Perichondrium	None	
	Bone	None (see text)	Absent [1]
	Periosteum and endosteum (osteoblasts and capillaries)	None	Moderate [1]

is accompanied by a corresponding decrease in alkaline phosphatase. 2. Normal adult hyaline cartilage, which does not ossify, contains in its intercellular matrix a large amount of chondroitin sulphate, but little or no alkaline phosphatase. 3. The normal embryonal ossification process is characterized by a rapid local disappearance of chondroitin sulphate, and concurrently by the appearance of large amounts of alkaline phosphatase.

With the metachromatic staining technique, the author has usually not been able to demonstrate any chromotropic substance in the perichondrium or periosteum (Table I). Newly formed embryonic bone (both endochondral and perichondrial) and adult bone are free of histochemically demonstrable ester sulphates in the calcified matrix. This finding is in accordance with that of Meyer, who, by chemical analysis, could not verify the conception of earlier authors [4, 8] as to the supposed content of chondroitin sulphate in spongy bone.

The findings of the present histochemical investigation support the statements by Logan and, to some extent, those by Hass, previously referred to. These findings, however, give more information as to the actual site of depletion of chondroitin sulphate than those by Logan. Obviously, the content of chondroitin sulphate is diminished in the vesicular layer of the "hypertrophic" cartilage, and almost all chondroitin sulphate has disappeared from the intercellular medium of the degenerating cartilage in places of osteoblast activity. Thus, it seems most probable that *removal of the acid chondroitin sulphate is a prerequisite for the action of the bone-forming osteoblasts.* Corresponding observations have been made in intramembranous ossification (Table I).

The manner in which the removal of acid substance is effected requires some discussion. We should consider the possibilities of more rapid absorption or inhibited production

TABLE VI

ANALYSIS OF FORTY FAILURES OF BONE-GRAFT OPERATIONS

Apparent Cause	Inlay	Onlay	Dual	Total No.	Total Per cent.
Fracture of graft	2	10	2	14	35.0
Infection with sequestration of graft	1	3	8	12	30.0
Sclerosis of one or both fracture fragments	0	4	1	5	12.5
Extensive decalcification of fracture fragments	1	3	1	5	12.5
Short graft (three inches or less)	1	2	0	3	7.5
Inadequate fixation near joint	0	1	0	1	2.5
Total cases of non-union	5	23	12	40	100.0

A second or subsequent attempt to produce union was most successful with the dual type of graft. Of the forty failures, subsequent repair was attempted in thirty-two cases which were followed. Of the ten onlay grafts used, there were six delayed unions and four non-unions. On the other hand, twenty-two dual-type grafts were used at a second or subsequent attempt at repair, with only nine delayed unions and no instances of non-union.

SUMMARY

This study of the end results in the various types of bone-graft operations has permitted a follow-up as to the healing time of 358 of the 580 bone-graft procedures which came under our observation from June 1942 to September 1946. Approximately one-third of the patients studied were transferred from other hospitals, and came under observation during the healing period. No attempt was made to separate the two groups, and the statistical tables represent a composite study.

There were 40 failures (11.2 per cent.). Of the remaining 318 cases, there were 34 inlay grafts with an average healing time of twenty-seven weeks, 121 onlay grafts with union in an average of twenty weeks, and 163 dual-type grafts that had union by an average of the nineteenth week. Of this group, 180 (56.6 per cent.) had delayed union beyond the sixteenth week. The distribution as to type and percentage of the grafts with delayed union was as follows (Table V): inlay, thirty-one (91.2 per cent.); onlay, seventy (57.8 per cent.); and dual, seventy-nine (48.4 per cent.). These end-result figures are particularly significant in view of the different types of clinical conditions for which the three types of grafts were usually employed.

Delayed union of bone grafts, used for the bridging of defects, occurred in five of eight cases in which the inlay type of graft had been used, and also in five of eight cases in which the onlay type of graft had been used; there were three instances of non-union in each group (Table VII). However, of the 112 dual grafts used for the bridging of defects, there were only twenty delayed unions and no failures without complicating factors.

Failure of union near joints was treated very successfully by the dual-type graft, there being only four cases of delayed union and no non-unions without other cause among fifty-four cases (Table VII). All inlay grafts resulted either in delayed union or non-union; and onlay grafts were unsuccessful in four cases and united after delay in six of sixteen cases of non-union near a joint.

Sclerosis of one or both of the fracture fragments was present in forty-seven cases. Of the five inlay grafts used in this type of case, there were four delayed unions and one failure of union. Seventeen such cases had onlay grafts, with ten delayed unions and five non-unions. However, of the twenty-five dual-type grafts employed in the presence of sclerosis, eighteen resulted in delayed union and one in non-union.

Severe decalcification of the fracture fragments was present in forty-nine of the cases

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DISCUSSION

BONE GRAFTS

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onlay grafts fixed with metal screws. On the tibia, a modified Hoglund operation, with sliding intramedullary and onlay grafts, gives excellent results.

DR. W. A. BISHOP, JR. (closing): General Kirk made the statement that, in the latter part of our series, we discontinued sliding inlay grafts. I do not want to leave that impression. Due to the type of condition encountered in the series, and to our experience with the prolonged healing time of the inlay graft in all but the delayed unions in which an active healing process was present, that type of graft was considered to have few indications. As to the dual-type graft versus the massive onlay graft, we wish to repeat that the massive onlay graft is the choice in the uncomplicated cases of non-union of the long bones. However, as was borne out by the statistical reports, the dual graft should be used for the earliest return of function, under the circumstances listed in the Summary.

I am sorry that we are unable to tell you the number of compound, comminuted fractures in the series. As a general statement, in the early days, there were an estimated 30 per cent., but, near the close of the War, the non-unions with early compounding of the wound had increased to as high as 95 per cent.

As to infections, the rate increased as the series progressed, for two apparent reasons. In the first place, we were dealing with a much more serious type of case, which had eventually reached the stage in the treatment at which bone-grafting was indicated. Also, the administration of penicillin to great numbers of patients who had never received it before resulted in the prevention of infection in all cases; but as penicillin-treated cases—some with penicillin-resistant organisms—came to bone-graft surgery, the drug was not effective where it was needed most, and the percentage of infections increased rapidly.

studied. Four inlay grafts resulted in three cases of delayed union and one of non-union; nineteen onlay grafts resulted in delayed union in fifteen and failure in four; and, of the twenty-six dual-type grafts used in this condition, there were twenty-two delayed unions and one non-union.

A second or subsequent graft after an initial failure also resulted in slow union. In this group, there were ten onlay grafts with six delayed unions and four repeated non-unions. However, of the twenty-two dual grafts used after a previous failure, there were only nine delayed unions and no non-unions.

Fracture of the graft occurred in twenty-five of the cases. Of these, fourteen appeared to be the direct cause of non-union, and eleven healed in an average of twenty-seven weeks from the time of the fracture.

Postoperative infection was encountered in thirty-nine cases. In thirteen of these, there was sequestration of the graft; and failure of union occurred in all but one. In the twenty-six cases without sequestration, delayed union occurred in thirteen cases, and in one other case a fracture of the graft failed to unite.

Short grafts are seldom, if ever, indicated. Of the twenty-one grafts which were three inches or less in length, twelve resulted in delayed union and five in non-union.

Failure to provide a flat surface for the reception of the graft was obvious in thirty-five cases, there being thirteen delayed unions and two failures in the series.

The use of plates in conjunction with bone grafts was employed in three inlay grafts, twenty-three onlay grafts, and twelve grafts of the dual type. The healing time was the same, with or without the use of the plate. There were no fractures in this group of thirty-eight cases, and early mobilization was possible in all instances.

Adequate fixation of the graft with screws will permit early mobilization of the adjacent joints. When this routine was followed, it resulted in marked reduction of the length of the convalescent period, and often in reduction of the proportion of patients with permanent disability, as compared to similar cases treated by other methods.

CONCLUSIONS

The ten rules in bone-graft surgery for the early return of function are as follows:

1. Inlay grafts (Albee type) should be used only in cases of delayed union, where an active healing process is already present.
2. Onlay grafts are the choice in the uncomplicated cases of non-union of the long bones.
3. Dual-type grafts are indicated as follows: (a) to bridge a defect; (b) to repair non-union near a joint; (c) in the presence of marked decalcification of the ends of the bone; (d) when there is sclerosis of one or both of the major fracture fragments; and (e) when a previous bone graft has failed.
4. The removal of at least two-thirds of the thickness of the cortex in the preparation of the bed for the reception of the graft will result in earlier union and fewer failures.
5. Careful stripping of the periosteum to give a continuous sheet at the time of exposure and the judicious use of one or more longitudinal slits in the periosteal cuff on the side opposite the graft will allow the soft-tissue covering of the bone to be shifted forward and to be sutured without tension, when onlay or dual grafts have been used.
6. Short grafts are seldom, if ever, indicated. Onlay grafts should approximate seven inches, as nearly as the particular bone involved and the site of the fracture will permit.
7. A second or subsequent attempt at repair should be made without delay, following the fracture of a graft.
8. Early mobilization of the involved extremity will reduce the temporary or permanent disability, or both.
9. Rigid fixation of the graft is mandatory, if early supervised use of the extremity is to be practised.

position from the back to the front of the humerus was of no assistance, as the gain in length is present only when the elbow is flexed.

PROCEDURE

Invariably, patients were admitted in shoulder spicas, which usually had been applied at the time of the primary débridement. The wounds were closed by delayed primary suture, and a Kirschner wire was inserted through the olecranon. Until all the sutures could be removed, the limb was placed in overhead traction (Fig. 1) which had the following advantages:

1. Oedema was diminished markedly, hastening wound healing.
2. Daily electrical stimulation of the muscles of the exposed forearm was possible.
3. Traction force could easily be evaluated to permit alignment, but without distraction of the fragments.

In approximately two weeks, the stitches were removed, and a shoulder spica was applied without discontinuing traction. The Kirschner wire was removed at this time.

In those cases in which a large nerve defect was suspected, comparative roentgenograms were taken of the fractured bone and of its fellow on the normal side. Thus it was learned that, in two of the cases (Cases 1 and 2), shortening of 1 centimeter and of 3.8 centimeters, respectively, had existed prior to operation.

Two weeks after the skin wound had healed com-

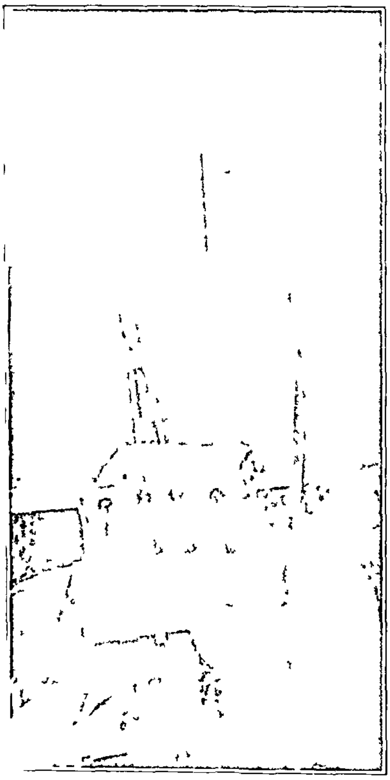

FIG. 1

FIG. 1

Illustrates type of traction employed immediately after secondary closure, and maintained until wounds had healed. Arm is suspended above chest by wire through olecranon. Weight is adjusted so as to balance arm weight and to cause no distraction of fragments. Pressure dressing and elevation reduce oedema. Forearm is readily available for galvanic stimulation.

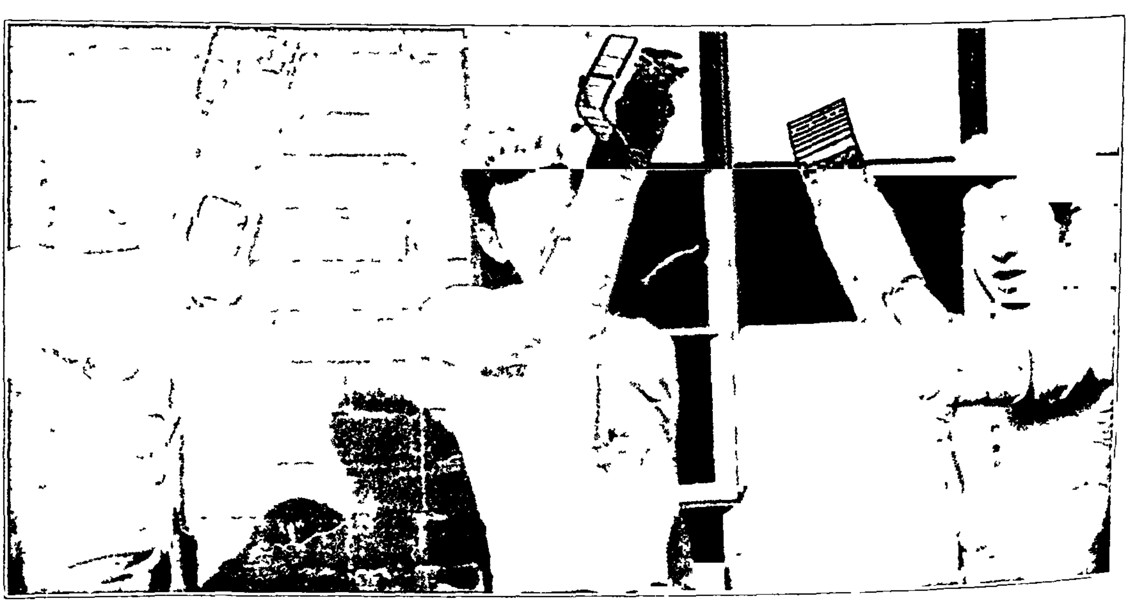

FIG. 2

Type of cast employed after discontinuation of traction, but prior to combined operation. A similar cast was applied immediately after operation. Windows are placed in cast to permit stimulation of paralyzed muscles by galvanic current. Finger extension is aided by elastic bands.

These are most interesting observations on success and failure as regards various types of grafts used, although many other factors are considered to have a bearing on healing time and success of union.

More interesting to me than the statistical studies are the successful results,—the union secured. There were a total of forty failures, or 11.2 per cent. in this series. Yet the indication for bone-grafting was for bridging bone defects of from one to five inches in 128 cases, marked decalcification of fracture fragments in 49, and sclerosis in 47. There were undoubtedly soft-tissue loss, moderate to severe chronic healed osteomyelitis, and circulatory insufficiency; and extensive scarring surely followed those gunshot wounds which required preliminary excision and adequate skin coverage before bone-grafting could be attempted. I wonder in how many of these 358 cases the fracture had been compounded and comminuted by the original injury or by the surgeon first treating the case, and how many of them had been infected, either slightly or severely.

Fracture of the graft accounted for fourteen or 35 per cent. of the failures. This may be attributed, from a practical standpoint, to improper mobilization or protection; or again it might be the fault of the patient, and result from a condition over which the surgeon had little control. "Pilot error" accounted for 7.5 per cent. of failures,—the graft was three inches or less in length. Infection was responsible for only twelve or 30 per cent. of the cases which failed.

It is interesting to compare the low incidence, twelve cases or 3.3 per cent., of graft loss from infection in this series of 358 cases in World War II with a loss of twenty-two cases, or 17 per cent., which occurred in 129 cases reported by me in 1924 from World War I. Chronic osteomyelitis was the rule in the majority of cases in World War I following compound fractures. The control of infection required months of treatment, and this resulted in non-use and atrophy of muscles and bone. Bone-grafting was not attempted until the wound had been healed six months or more, with the revision of the wound scar tissue and its removal and skin coverage. In this War better primary surgery, assisted by sulfonamides and penicillin, as Dr. Phemister has pointed out, reduced osteomyelitis to the minimum and permitted definitive surgery several months earlier than in World War I. The onlay and dual methods of grafting were unknown at that time. Henderson used and taught the use of the massive graft, which was the graft ordinarily used.

The only failure in twenty-eight bone grafts for non-union following simple fractures, or in which there had been no previous infection reported by me at the same time, was one "fishtail" graft in an ulna, which was too small. This was the "pilot error" again. There were no infections in these twenty-eight cases. Kangaroo tendon and catgut were used to secure grafts in those days, following the teaching of Albee. No screws were used in my series. Kangaroo tendon or catgut in this devitalized tissue and bone frequently acted as a foreign body and caused failure. For that reason grafts were made self-retaining, wherever possible.

It is felt that the preparation of the graft bed in regard to the soft tissue and the skin covering of the extremity is more important than the selection of the graft to be used, and that this must be accomplished before the graft is attempted.

I am sure that Dr. Phemister is correct when he states that the incision through which the graft is done should be in tissue undamaged at the time of the injury, if this is possible. Too often, in war wounds and in severe compound fractures, it is not possible.

In selecting the type of graft to be used for non-union and loss of substance in shafts of long bones, in the diaphysis, and in flat bones, as has been pointed out in these papers, one must consider certain factors and others which I want to discuss. In a paper before The American Orthopaedic Society last year, Abbott recommended the use and showed the advantage of iliac bone as a graft in the diaphysis of long bones, for non-union in flat bones and cortical bone, and for non-union and lost substance in the shafts of long bones. I heartily agree, from my present experience. We had felt, until this analysis was made, that the massive onlay-type graft was the graft of choice for non-union, with or without lost substance, in the femur and humerus and, in a modified form, in both bones of the forearm; and that it should be fixed securely with screws and should be in contact with the medullary blood supply. We felt that this graft should be of sufficient size to give stability as an internal splint when applied, that it should be supplemented with cancellous bone from the tibia or ilium; and that in the bones of the leg an inlay-type transplant from the good leg, made self-retaining, was the procedure of choice and far superior to the sliding graft in a bone, which disturbed its medullary blood supply. Sclerotic bone presents a problem, particularly in the typical pseudarthrosis. Personally, I look upon sclerotic bone as scar tissue of bone in which there is no blood supply and, frequently, through which no new blood channels can be formed. I believe that its removal is indicated except for a supporting bridge to a graft, and that the scar tissue between the sclerotic ends should be removed for the same reason. In bone which is atrophic from lack of blood supply, infection and non-use frequently produce a cortex no thicker than an eggshell, through which one can easily push a hemostat. The medullary canal is filled with fat. In this type of bone it is impossible to fix an onlay graft with screws, as there is not enough cortical bone to hold. Neither can an inlay be made into such bone and secured there. A dual-type graft must be used to secure the screw to the fragments of the bone end. This is the type of bone in which an intramedullary graft can be used, after the ends of the fragments have been removed. Extensive stripping of periosteum is, therefore, not necessary; it does not interfere with medullary circulation, nor does it deprive the bone fragments of the circulation that is present at the time of surgery.

pletely (with loss of the last crust), a nerve exploration was done. Block of the brachial plexus was produced with procaine. A straight, oblique incision, beginning three fingerbreadths below the acromion posteriorly and paralleling the lateral border of the long head of the triceps, was extended to the dorsolateral surface of the forearm, following approximately the course of the radial nerve. The cubital-flexion crease was avoided by having the incision pass just anterior to the lateral epicondyle. (Old scars were excised, whenever possible.) The segment of nerve between the teres major and the lateral head of the triceps was exposed by separating the long head from the lateral head of the triceps, and retracting the lateral head of the triceps outward. Additional exposure at the proximal end may be obtained by section of the combined musculotendinous insertions of the teres major and latissimus dorsi with the arm abducted, and then by adducting the arm to the side. The segment of the nerve distal to the penetration of the lateral head of the triceps was exposed anterior to the intermuscular septum. The deep branch of the radial nerve, which penetrates the brachioradialis, was exposed by retracting this muscle group volarward. This exposure, although interrupted by the intact fibers of the lateral head of the triceps above and of the brachioradialis below, seemed superior to the posterior approach described by Henry, because it allowed extension into the forearm and gave adequate exposure to the dorsal antibrachial cutaneous nerve, which was frequently severed.

The nerve was identified above and below the lesion, and was dissected free. The defect of the nerve was not always exactly at the site of the fracture. Occasionally it was found that a missile had passed obliquely through the extremity and had injured the nerve at a point distant from the site of fracture. After the nerve lesion had been disclosed, an estimate was made of the amount of nerve defect to be overcome; the nerve ends were freed from the scar; and the nerve trunk was mobilized as far proximally and distally as would contribute to approximation of the segments. It is noteworthy that adhesions of the nerves to the osteoid tissue at the site of the fracture were especially dense. If it were decided that the bone was to be shortened, the nerve ends were first packed away from the fracture site.

FIG. 4-A

METHODS OF BONE SHORTENING

Under normal conditions, bone grafts would have been substituted for the methods used in at least two of the cases. The methods used were as follows:

A. *Transverse Parallel Section*

Transverse parallel section of the fragment ends, with the flat surfaces left to be adjusted by coaptation and held by a plate, was carried out in Case 3 (Figs. 3-A, 3-B, 3-C, and 3-D). Although union occurred in this case, there was the risk that absorption at the fracture line might have led to non-union, because the fragments were held apart by a plate.

B. *Step Method*

In the step method, apposing flanges from each fragment overlap and are held by a plate (Case 4). Although this method provides maximum surface approximation and stability, it requires almost intact fragments upon which to fashion the flanges, and hence is rarely applicable (Fig. 4-C).

FIG. 4-A

Case 5. Patient was injured March 24, 1945. Secondary closure was carried out five days after injury, and combined operation forty days after injury. Roentgenogram of fracture, taken on April 1. 1945.

CARTILAGE AND CHONDROITIN SULPHATE

II. Chondroitin Sulphate and the Physiological Ossification of Cartilage*

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From the Department of Radiopathology, Radiumhemmet, Stockholm

The normal endochondral and perichondrial ossification processes are characterized by degeneration and subsequent digestion of cartilage, as it is replaced by bone. Leaving the well-known morphological descriptions and turning instead to the actual happenings and main factors governing the ossification process, we are faced with complicated chains of cooperating events. The closed structure of the preosseous cartilage is suspended, and the same cartilage is confronted with a multitude of new biological factors, such as the primitive bone marrow with its fibroblasts, capillaries, and numerous enzymes. The destruction of cartilage, so easily brought about by the cells of the primitive bone marrow, is probably due to the action of proteolytic enzymes, which have not yet been demonstrated. Concurrently, lime salts are laid down by the action of osteoblasts, which probably produce alkaline phosphatase, a group of enzymes playing an important role in bone formation and calcification [11]. Histochemical investigations show that the intercellular medium of normal hyaline cartilage (tracheal or bronchial) is devoid of alkaline phosphatase [1, 5]; but, in places where ossification is going to occur, large quantities of this enzyme have been demonstrated [1, 9].

Incomplete quantitative data as to the changes of chondroitin sulphate during the ossification and calcification of cartilage are to be found in the literature. Logan stated that calcification of cartilage was preceded by a loss of organic sulphates,—namely, a loss of chondroitin sulphate. Thus he found a decrease in the acid constituent of cartilage, and this was considered to favor the precipitation of the inorganic salts. The same results were reported by Hass, who analyzed the content of chondroitin sulphate in human costal cartilage. He noted a gradual depletion of the ester sulphate with increasing age, and thought the mechanism for the maintenance of the intercellular matrix to be deteriorated. Hass made the interpretation that "...maintenance of a high level of chondroitin-sulfuric acid is a device by which cartilage is protected against calcification".

The investigations mentioned are of special interest, and pertain directly to the histochemical results to be presented.

Some young rats (from one to twenty-one days old), rat embryos (25 and 34 millimeters in length), and one human foetus (82 millimeters in length) were employed in this study. Sections from *Anlagen* of occipital bone, mandible, nose, hands, legs, feet, and fingers were used. After fixation in basic lead acetate (4 per cent. aqueous solution) or in formaldehyde solution, parts of the skeleton were sectioned without previous decalcification. Staining was performed with toluidine blue (0.1 per cent.) in alcohol solutions of different concentrations (1, 30, 50, 60, and 80 per cent.), according to the technique described previously by the author [13, 14]. All sections were of the same thickness (5 microns) and were treated in exactly the same manner. Thus, according to statements in the first portion of this report [15], the content of chondroitin sulphate could be estimated approximately, and the occurrence of this substance could be localized histochemically.

The present observations are recorded in Table I; and a comparison is made with available data on the occurrence of alkaline phosphatase in the corresponding tissues, according to other investigators.

From the results in Table I, the following conclusions are fairly evident: 1. During the early embryogenesis of cartilage, the gradual increase in content of chondroitin sulphate

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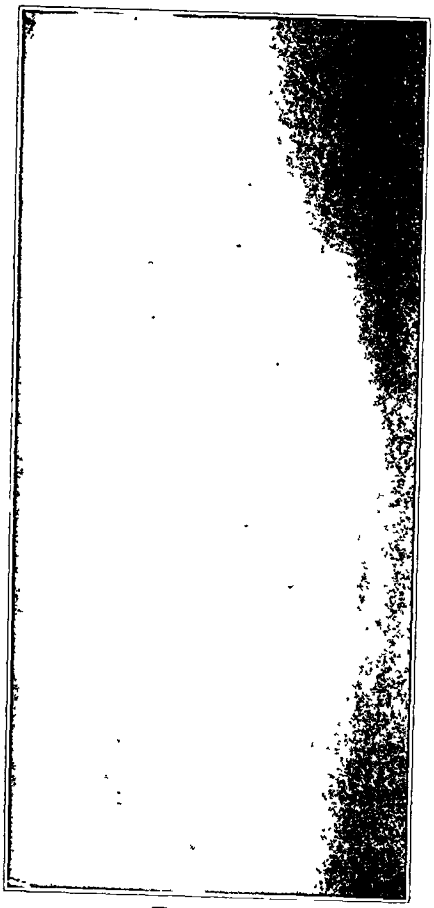

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 2. Patient was injured by mortar, January 26, 1945. Secondary closure was performed ten days after injury, and combined operation sixty-two days after injury. Shows original roentgenogram of the fracture.

Fig. 5-B: Showing details of procedure. Note ability to lengthen or shorten by sliding the fragments.

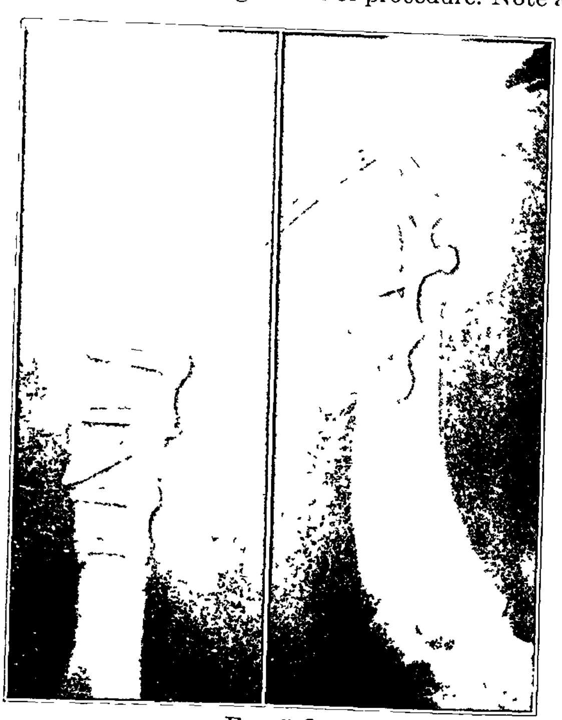

FIG. 5-C

FIG. 5-D

Fig. 5-C: Roentgenograms taken immediately after combined neurorrhaphy and bone shortening of 7 centimeters by the oblique method. Distal oblique fragment was comminuted, but was sufficiently adherent to act as one piece.

Fig. 5-D: Roentgenograms taken January 29, 1946, nine months after operation. Bony union was complete in five months, and motor regeneration of radial nerve was 75 per cent. after ten months.

of chondroitin sulphate, but this probably occurs by disintegration of the ester sulphate in question. It was emphasized in a previous paper [15] that the native chondroitin-sulphate molecule presents a remarkable susceptibility to weakly alkaline reactions. A shift in hydrogen-ion concentration to the alkaline side seems to be sufficient to depolymerize the chain molecule, which would explain the histochemical observations. Several other factors might also be involved -namely, proteolytic enzymes and other enzymes—but lack of additional data prevents further discussion.

Avoiding all teleological allusions to the "protective action" of chondroitin sulphate [3], we may summarize the present results as follows: The embryonic hyaline cartilage contains an acid intercellular substance. One of the first demonstrable changes, when ossification and calcification are initiated, is found to be a disappearance of this acid material. After the removal of chondroitin sulphate, the specific osteoblast activities are exerted. The precipitation of lime salts is directed by alkaline phosphatases, which demand an alkaline reaction for hydrolytic activity [1, 9, 10, 11]. The increased alkalinity is probably effected by the primitive bone marrow with its blood vessels. The same mechanism seems also to be sufficient for explaining how the chondroitin sulphate is removed from the preosteal cartilage.

As to the "oversimplified interpretation" of Hass, actually the chondroitin sulphate of cartilage can not be regarded as a protective mechanism against calcification. With reference to the previous conceptions [15], we have to retain the opinion that chondroitin-sulphuric acid, by its acid reaction, in a general way favors some enzyme reactions, while inactivating other enzyme systems. Furthermore, the intercellular medium of normal adult cartilage is devoid of alkaline phosphatase [1, 5, 9], and thus the precipitation of lime salts is prevented.

A decrease in the content of chondroitin sulphate is also noted under physiological conditions [15], in amianthoid degeneration, and in fibrous metaplasia of cartilage [2, 12]. This the author has been able to confirm from his own material. Such conditions are not necessarily combined with calcification.

SUMMARY

By means of the metachromatic staining technique, the distribution and approximate amount of chondroitin sulphate in embryonic cartilage were studied during the ossification process. Previous statements by Logan have been corroborated, and additional data are presented. Thus the ossification of cartilage is evidently *preceded* by a loss of chondroitin sulphate, which begins in the "hypertrophic" vesicular layer of cartilage. In places where osteoblast activity is actually exerted, all chondroitin sulphate has usually disappeared. The disintegration of the ester sulphate is probably effected by a shift in hydrogen-ion concentration, by enzyme action, or both. From a morphological point of view, the ingrowing blood vessels and fibroblasts of the primitive bone marrow carry the active mechanisms which are transferred to the intercellular medium. The destruction and removal of the chondroitin sulphate seems to be a necessary link in the chain of events producing an alkaline medium, which is a prerequisite for the action of alkaline phosphatase.

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TABLE I

SUMMARY OF CLINICAL FINDINGS

Case	Time from Injury to Secondary Closure (*Days*)	Time from Secondary Closure to Combined Operation (*Days*)	Time from Injury to Combined Operation (*Days*)	Direction of Missile Through Arm	Area of Bone Comminution (*Cm.*)	Amount of Bone Shortening (*Cm.*)	Nerve Tissue Resected* (*Cm.*)
1 E. G. B.	25	43	68	Posterior to anterior	9.0	5.0	4.0
2 R. A. F.	10	52	62	Posterior to anterior	10.0	7.0	4.5
3 F. W.	12	47	59	No record	1.0	2.5	5.0
4 L. C. S.	13	47	60	Lateral to medial	7.0	4.4	5.2
5 C. E. T.	5	35	40	Anterior to posterior	2.0	3.0	5.0
6 C. L. P.	24	43	67	No record	1.0	3.5	5.0
7 E. H. S.	17	22	39	Anterior to lateral	8.0	4.4	8.0
8 M. N.	18	75	93	No record	5.0	2.5	5.0
Averages	15.5	45.5	61.7		5.4	4.0	5.2

* This is the actual amount of tissue resected, not the length of the gap between nerve ends.

INTERNAL FIXATION OF BONE AND NEURORRHAPHY

Combined Lesions of Radial Nerves and Humerus Fractures

BY MAJOR WILLIAM K. MASSIE AND MAJOR ARTHUR ECKER

Medical Corps, Army of the United States

Before the recent advances in chemotherapy, when a wound resulted in a severe lesion of a peripheral nerve, together with a compound fracture, the fracture was treated first and the nerve injury later. Such precedence was required especially in war wounds, because of the considerable risk of infection. Paralyzed muscles were immobilized in plaster for many months, which resulted in incapacitating muscle atrophy and stiff joints. The addition of sulfonamides and penicillin to judicious surgery has permitted more prompt healing of contaminated wounds, and the relatively early use of non-absorbable materials for repair of both bone and nerve. As the risk of infection has diminished, more vigorous measures have been used to maintain and to restore the function of the limb. Galvanic stimulation [11, 12, 19], begun a few days after injury, has minimized atrophy, tended to maintain the blood supply of paralyzed muscles, and prevented adhesions of tendon sheaths and contractures of joint capsules. Furthermore, early surgery on the peripheral nerves has brought regenerating nerve fibers to paralyzed muscles many months, and sometimes years, earlier than was the case formerly, when attention was directed primarily to the healing of the compound fracture.

In the early months of 1945, the authors had under their care, in a General Hospital in England, more than two hundred cases of severe nerve lesions, associated with fractures of the long bones. The majority of the wounds had been caused by shell fragments. These cases were treated according to a program laid down by Spurling. This group included eighty-four cases of humerus fracture, in which exploration of the radial nerve was carried out within a few weeks of injury. In all except two, either neurolysis or satisfactory anastomosis was performed. Of the total group of eighty-four cases, forty-one (48.8 per cent.) required neurolysis only; thirty-five (41.7 per cent.) required nerve suture only; and eight (9.5 per cent.) required internal fixation of bone with shortening, and nerve suture. Each of the eight cases presented a radial-nerve lesion, associated with a compound fracture of the humerus. This report will be confined to an analysis of these eight cases, which had slightly less than a year of follow-up study, and a discussion of the treatment used.

Bone shortening is mentioned in the literature, for the most part, as a means for equalization of limb length [3, 22, 24, 28, 30, 31]. Few actual cases have been reported of shortening of a bone to allow neurorrhaphy, however, although the procedure has been considered for many years [5, 6, 23, 27].

BONE FIXATION AND SHORTENING

It has been shown by Platt that the existence of non-union of fractures, contiguous with sutured nerves, has retarded and prevented recovery, because of tension and friction at the suture sites. In the present series, neurorrhaphy was done at an average of 61.7 days after injury. At this time, the likelihood of non-union could be predicted with fair accuracy. In four of the eight cases, non-union could have been expected, if no operative intervention had been undertaken. In every instance, after each nerve segment had been freed from its bed and resected back to normal-appearing nerve bundles, the hiatus was too great to be overcome by flexion of the distal portion of the extremity without approximation of the nerve ends under considerable tension. Rather than to suture under prohibitive tension, with the knowledge that, as the extremity was subsequently extended, this tension would be increased, skeletal shortening was elected. Danforth's method of radial-nerve trans-

This patient was checked by one of the authors, and the angulation does not seem to interfere in any way with function. The permanent effect of the shortening is a little difficult to assess. The flexion contracture of the elbow noted in each case is also quite apparent in humerus fractures of comparable extent, which have been immobilized for prolonged periods [8]. However, this should improve steadily, if the muscle power of the biceps and triceps has not been weakened. All examiners, upon whose opinion we must rely for this follow-up study, agree that muscle power appears normal and that flexion contracture is the result of capsular contracture due to immobilization.

RESULTS OF NEURORRHAPHY

The data for this report were collected on an average of 8.4 months after neurorrhaphy (Table I), so that end results of nerve regeneration could be obtained in only Cases 4 and 5. In Case 4 there was complete recovery in ten months with only mild hypaesthesia; in Case 5, return of both sensation and motor function was considered complete in six months. The brachioradialis was rated as *poor* (25 per cent.). All other muscles were rated as *normal* (100 per cent.). Cases 1, 2, 3, 6, 7, and 8 seemed to be progressing well at the time of reporting, with partial return (Table I). Voluntary muscle return was rated as *normal* (100 per cent.) in one case, *good* (75 per cent.) in three cases, and *fair* (50 per cent.) in the remaining two cases. The progression of the Tinel sign suggested that further improvement could be expected. The value of this test, however, is not beyond question.

DISCUSSION

The authors believe that shortening of the humerus is indicated in certain cases, such as those of this series. It permits neurorrhaphy to be done materially earlier, and the results are not jeopardized by tension and traction of the concomitant unstable fracture.

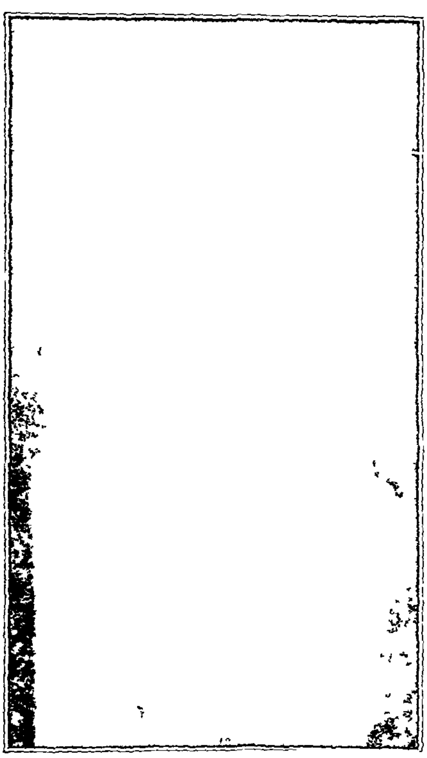

FIG. 7-A

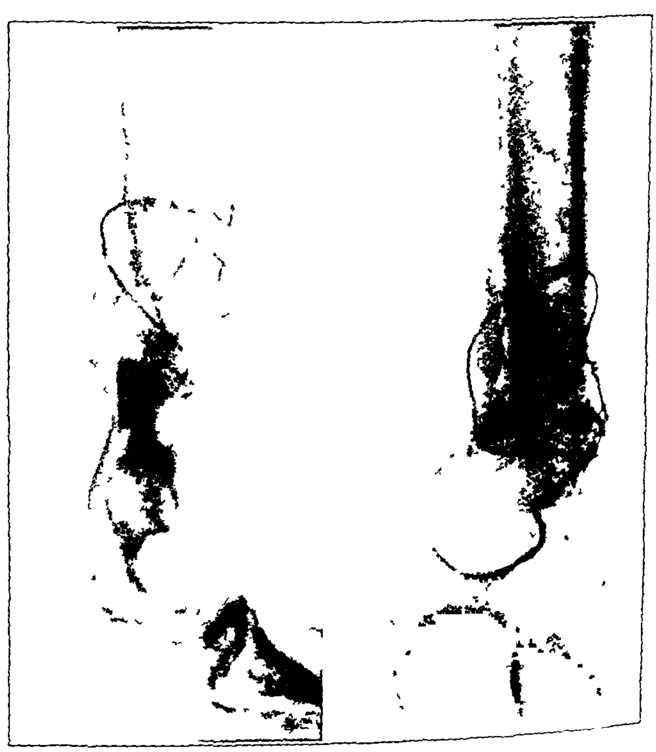

FIG. 7-B

Fig. 7-A: Case 8. Patient was injured March 4, 1945. Secondary closure was carried out eighteen days after injury, and combined operation ninety-three days after injury. Roentgenogram of fracture, taken March 5, 1945.

Fig. 7-B: Roentgenograms taken January 28, 1946. At operation the bone was shortened 2.5 centimeters. The oblique fragments were prevented from telescoping by a single wire loop, penetrating both fragments. Anteroposterior angulation was prevented by a double wire figure of eight. Bony union was complete in three and one-half months. Motor regeneration was 75 per cent. after seven months.

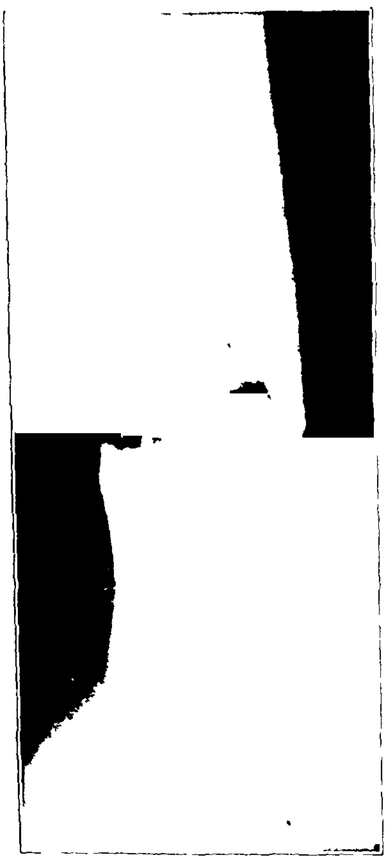

FIG. 3-A

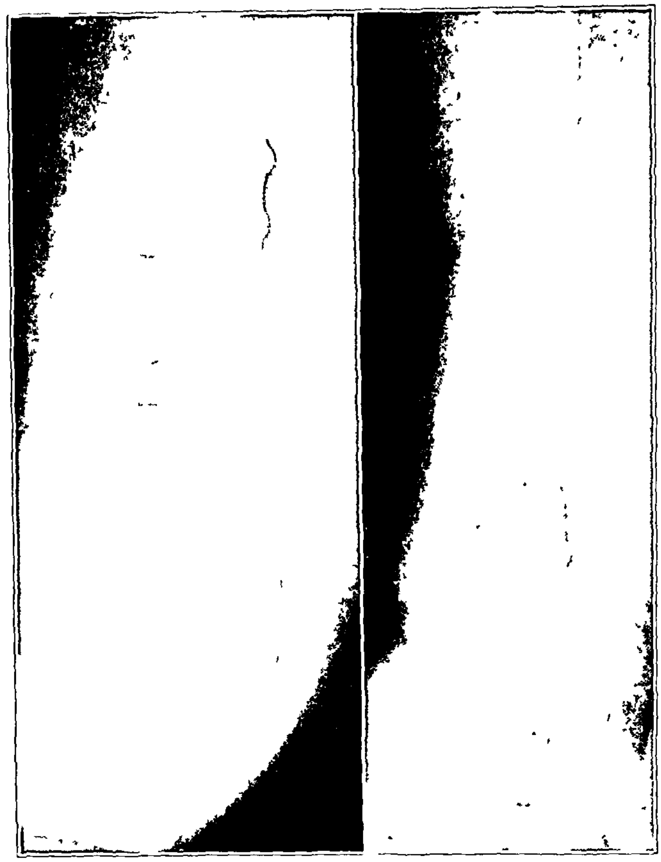

FIG. 3-B

Fig. 3-A: Case 3. Patient was injured by shell fragment on October 1, 1944. Secondary closure was carried out twelve days after injury, and combined operation fifty-nine days after injury. Roentgenogram of fracture, October 1, 1944.

Fig. 3-B: Roentgenograms following combined neurorrhaphy and bone shortening; a 2.5 centimeter transverse section of bone was removed on December 1, 1944. The fracture was solid at the time of operation. Note gap between fragments. Absorption at fracture site may increase this gap.

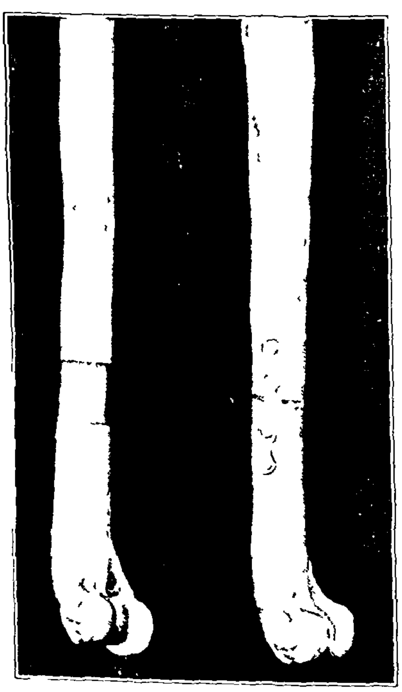

FIG. 3-C

Showing method used.

FIG. 3-D

Bony union complete in five months. Complete regeneration of motor fibers of radial nerve in ten months.

average of at least three weeks, and made it impracticable to treat these patients in the Zone of Communications.

In Table I is recorded the area of the comminution in centimeters. When compared with the actual amount of bone shortening attained, it is obvious that in most cases the shortening was accomplished without the ablation of any uninjured bone.

Correlation of the amount of bone damage to the amount of nerve resected depends upon such variables as the immediate care after injury, and the direction and speed of the missile. Only very broad and indefinite conclusions can, therefore, be drawn. It was noticed repeatedly, and is borne out by perusal of Table I, that missiles which entered from such a direction as to hit the bone before they reached the nerve caused more extensive damage, and that the damage was inversely proportionate to the speed of the missile.

Penicillin was used before and after operation in each case. The authors are convinced that the absence of any infection, following a major procedure performed on an extremity in which open granulation had so recently been present, was due to the use of this substance.

SUMMARY AND CONCLUSIONS

1. Eight cases of compound fracture of the humerus with radial-nerve laceration were treated by neurorrhaphy and bone shortening within an average of sixty days of the injury.
2. Bony union was complete in all cases.
3. Nerve regeneration was progressing satisfactorily in all cases, but was complete in only two at the time the patients were last seen. The importance of early and adequate galvanic stimulation of paralyzed muscles is stressed.
4. No ill effects are demonstrable from shortening of the humerus up to one-fifth of its length.
5. Early nerve suture is of paramount importance.
6. When suture necessitates prohibitive tension on the nerve, either at operation or during postoperative stretching, concomitant bone shortening in the arm is feasible. At present, this is considered preferable to tendon transplantation in the forearm at a later date.

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C. Apposition of Oblique Fragments

Apposing surfaces of oblique fragments are fixed by a plate, and a screw is placed across the fracture at right angles to the plate[20]. This method can be used most frequently (Cases 2, 5, 6, and 7), because the comminuted fragments are usually shaped obliquely. The exact amount of shortening can be altered, even after the surfaces have been ground to fit, merely by sliding the two surfaces over each other (Figs. 5-A, 5-B, 5-C, and 5-D).

D. Semi-Rigid Fixation

This is less desirable than methods of rigid fixation, but in certain conditions it is the only method applicable.

1. The use of one or more screws to hold badly comminuted fragments in place is mentioned only to point out that it is unsatisfactory. It is neither rigid nor elastic, and any strain at the fracture site tends to dislodge the fragments and to promote non-union. This method was not used on any patient in this series.

2. Wire fixation, applied in any pattern which will maintain the fragments in approximately the position attained at operation, was used in Cases 1 and 8. Figures 6-A, 6-B, 7-A, and 7-B illustrate two situations in which plates could not be used. Such massive destruction was present in Case 1 that the main fragments could not be approximated. A large separate fragment was utilized as a bone graft to bridge the defect, but it was too porous to fix with screws. In Case 8 the distal fragment was too close to the joint to permit the use of a plate. However, after wire fixation, the fragments could not be dislodged. The wires were placed to form a figure of eight, anterior and posterior to the fracture; and the two main fragments were prevented from overriding by a single wire loop. This provided

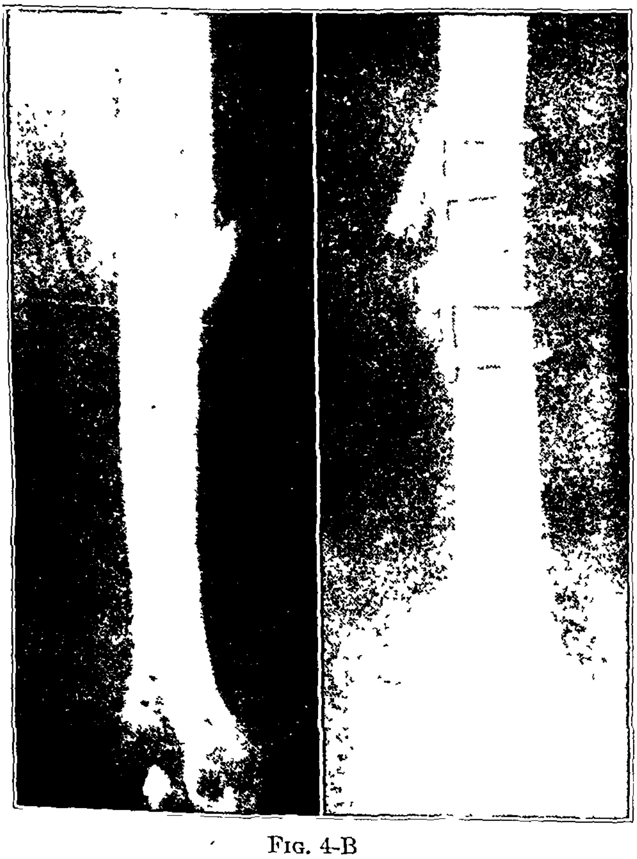

Fig. 4-B

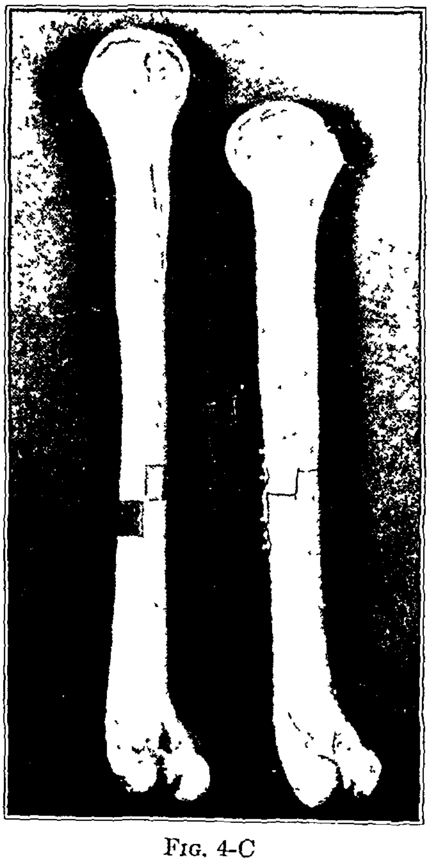

Fig. 4-C

Fig. 4-B: Roentgenograms taken July 25, three months after combined neurorrhaphy and bone shortening of 3 centimeters by the step method. Bony union almost complete. Motor regeneration of radial nerve was 85 per cent. after nine months.

Fig. 4-C: Shows technique used.

THE RELATION OF DISCOID MENISCUS TO CYST FORMATION AND JOINT MECHANICS

BY J. KULOWSKI, M.D., ST. JOSEPH. MISSOURI, AND
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The following case of discoid meniscus is reported because it brings up the still debatable question of the origin of cyst of the meniscus, and also because it apparently demonstrates a fundamental principle of the mechanics of the knee joint.

J. B., a white woman, aged twenty-one years, had complained of pain, tenderness, and swelling of the right knee of four months' duration; this was noted especially after active sports. A palpable swelling and significant widening of the lateral portion of the joint space suggested a cyst of the lateral meniscus. At operation, a small cystic mass and a completely discoid cartilage were encountered (Figs. 1-A and 1-B); the upper surface of the cartilage presented a remarkably eroded area.

These findings recalled the discussion in regard to the origin of meniscus cyst, and the automatic coaxial movements of the knee which must have caused the defect on the cartilage surface.

Of the current theories relating to the formation of cysts of the lateral meniscus, Ollerenshaw holds to their congenital origin. Other writers do not [8], mainly because of the paucity of cysts associated with malformation, and their denial [3] of the existence of an endothelial lining in cysts, spoken of by C. E. Jenkins, the pathologist who examined the specimens taken from all of Ollerenshaw's cases. Jenkins [7] stated that: "No reliance can be placed upon silver as a means of demonstrating cells". He illustrates this point by two photomicrographs in which a silver-stained section was counterstained with hematoxylin; the second staining brought out an increased number of cells, forming a sort of lining membrane in a cyst of the lateral meniscus.

The recorded instances of cysts associated with malformation do lend some support

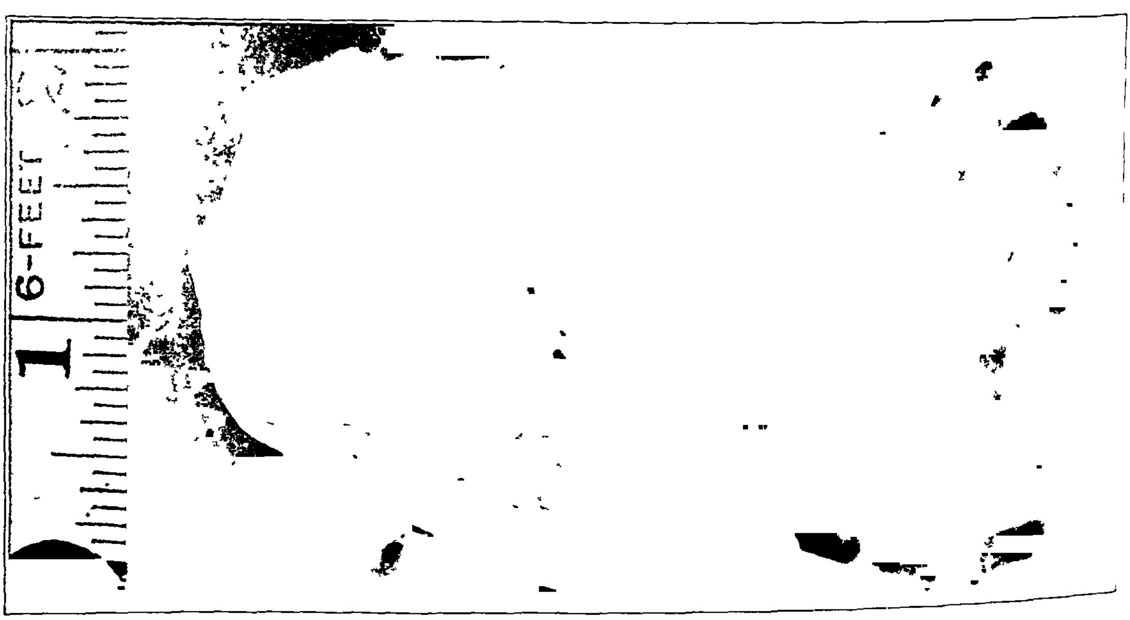

FIG. 1-A FIG. 1-B

Fig. 1-A: The femoral surface of the discoid cartilage is shown. The lower margin in the photograph is the anterior limit. The eccentric area of attrition and the complete attachment to the synovial membrane are notable.
Fig. 1-B: The tibial surface of the cartilage is intact. The anterior limit is in the upper part of the photograph.

Fig. 6-A

Fig. 6-B

Fig. 6-A: Case 1. Patient was injured by mortar on January 4, 1945. Secondary closure was carried out on twenty-fifth day after injury. Shows roentgenogram of injury, taken on January 29, 1945.
Fig. 6-B: Roentgenograms taken six weeks after operation (May 4), at which time only slight motion was obtained at fracture site, contrary to the appearance in the roentgenogram. At operation the humerus was shortened 5 centimeters. Note long posterior bone fragment, acting as a bone graft, which was held by wires. (Scarcely visible in reproductions.) Bony union was complete in seven months, although diameter of bone at fracture site was less than normal. Motor regeneration was only 50 per cent. after nine months.

good stabilization anteroposteriorly, but allowed motion in the lateral plane. Alignment could be controlled by plaster fixation.

After fixation of the fragments had been completed, absolute hemostasis was obtained. It was frequently necessary to place mattress sutures into the scar tissue to stop capillary oozing. Fifty thousand units of dried penicillin, diluted with dried plasma, were powdered and shaken into the wound. Neurorrhaphy was carried out according to generally accepted principles of nerve repair [26]. In the case of fractures in the middle third of the humerus, it was usually possible to bring some of the fibers of the lateral head of the triceps between the site of the fracture and the sutured nerve. This was done to minimize the formation of adhesions between the sutured nerve and the fracture site. It also prevented the later development of friction neuritis [9, 21]. However, it did tend to take up some of the slack of the nerve, and emphasized the importance of having shortened the bone.

At the end of the operation, the limb was fixed in a plaster cast which kept the shoulder in forward flexion and abduction, and the elbow in as much flexion as was necessary. A window was cut over the posterolateral aspect of the forearm to permit daily electrical stimulation (Fig. 2).

RESULTS OF BONE FIXATION WITH SHORTENING

As shown in Table I, firm bony union developed in all cases. In Case 1, a supplementary graft [4] might have been advisable to obviate subsequent fracture. In Case 8 a pronounced varus angulation was present, due to improper alignment in the cast (which could have been corrected easily had it been noted when the final postoperative cast was applied).

According to Steindler, the movement of flexion is essentially a pure rocking motion during the first 20 degrees, after which it becomes a gliding action of the tibia on the femur. During the latter excursion, 50 or 60 degrees of rotation occur. Flexion is started with an inward rotation of the tibia against the femur, and extension is completed by a reverse rotation. The ability to rotate the leg inward makes it possible for the leg to bring the foot forward in walking. As the swinging leg is set to the ground, the forward rotation of the pelvis results in an outward rotation of the limb. Then, as the foot deploys while the other free-swinging side of the pelvis comes forward, the standing knee goes into flexion and, with it, inward rotation of the tibia begins on the standing side. Since the longitudinal axis falls within the medial condyles, the lateral tibial condyle makes the greater excursions. Thus was the peculiarly directed erosion of the femoral surface of the cartilage, reported here, a prerequisite for the fulfillment of the coaxial movements of the affected joint.

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TABLE I (*Continued*)

Time from Operation to Complete Bony Union (X-ray Criterion) (*Months*)	Type of Fixation	Time from Neurorrhaphy to Follow-up Study (*Months*)	Muscles Showing Some Degree of Recovery	Recovery of Voluntary Motion	Amount of Elbow Motion (*Degrees*)
5	Wire	9	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis	Fair (50%)	70–145
4	Four-hole plate	10	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum communis, abductor pollicis longus	Good (75%)	55–155
8	Four-hole plate	10	Triceps, brachioradialis, extensor carpi radialis longus. extensor carpi radialis brevis, supinator, extensor digitorum communis, extensor carpi ulnaris, abductor pollicis longus, extensor pollicis longus	Normal (100%)	45–150
7	Four-hole plate	6	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, supinator, extensor digitorum communis, extensor carpi ulnaris, abductor pollicis longus, extensor pollicis longus	Normal (100%)	40–175
6	Four-hole plate	9	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, supinator, extensor digitorum communis, extensor carpi ulnaris	Good (75%)	85–155
8	Four-hole plate	7	Triceps, brachioradialis, supinator	Fair (50%)	No record
5	Four-hole plate	9	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, supinator, extensor digitorum communis, extensor carpi ulnaris	Good (75%)	60–165
7	Wire	7	Triceps, brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, supinator, extensor digitorum communis	Good (75%)	70–165
6.2		8.4			

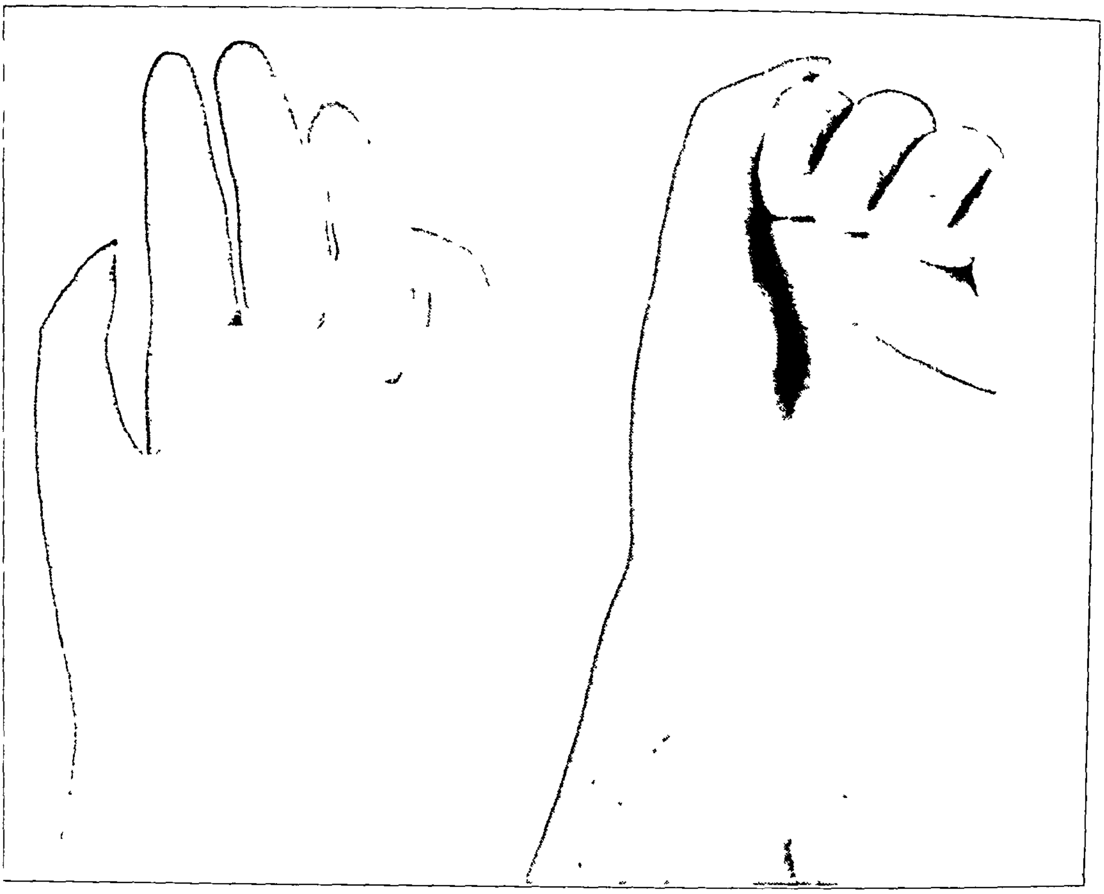

FIG. 1-A FIG. 1-B

The extensor carpi radialis longus has been transferred into the flexor digitorum profundus tendons to restore flexion power to the fingers. There had been extensive loss of muscle substance in the forearm. Photographs show fingers extended (Fig. 1-A) and flexed (Fig. 1-B), approximately two months after the tendon transfer.

bring the finger tips to within more than an inch of the palm, but each patient had a fairly strong grip for large objects.

One of these two patients was an Army sergeant, who sustained a severely lacerated wound, involving the left forearm, with considerable loss of flexor-muscle substance. A large abdominal pedicle graft was applied to the volar surface of the forearm. The median and ulnar nerves in the forearm were incompletely damaged. There was a fairly good sensation over the palm and the volar aspect of the fingers; and the intrinsic musculature of the palm was partially functioning. There was a severe adduction contracture of the thumb, and there was no power of flexion in the fingers or thumb. A Z skin plasty and a stripping of the adductor pollicis muscle from the thumb were done to relieve the contracture of this digit, and the extensor carpi radialis longus tendon was transferred into the flexor profundus tendons of the fingers. Figure 1-B shows the result of this tendon transfer, approximately two months after operation. The flexor pollicis longus was motivated by the brachioradialis at a subsequent operation.

Another patient in this group had a very badly scarred hand, with marked adhesions along the course of all flexor tendons in the palm and fingers; and the transfer was done after a tendolysis of the flexor tendons. There was very little improvement in this case, although the patient was last seen only five weeks after operation. The authors felt that all of these patients would continue to improve with further active use of their hands.

In the group of cases with nerve injuries, three patients achieved a strong grip with fingers touching the palm, and the fourth patient obtained flexion of his fingers to within one and one-half inches of the palm. As one would expect, the end results in this group were better, as far as flexion was concerned, than in the group with muscle damage, because

The tension under which suture of the nerve is done can be assessed and determined accurately. The authors feel that it is preferable to shorten the bone more and flex the elbow less, in order to obviate the postoperative stretch on the nerve required to extend the elbow. Highet and Holmes suggested nerve graft in this dilemma, but the grafting of large nerve trunks has not proved feasible clinically, although experimental work on animals is encouraging [29].

In a follow-up study of nerves which at operation had been sutured under tension or in a position which would subsequently exert tension, Highet and Sanders showed conclusively the dire results of tension. Of six cases of popliteal suture after extensive resection, one showed regeneration, and this was the only case in the series in which only six centimeters had been resected. Re-exploration in three cases showed intraneural hemorrhage with fibrosis, extending both proximally and distally to the suture line to such an extent as to prohibit resection and suture. The amount resected in each of the instances in which recovery failed did not exceed the more conservative estimate made by both Forrester-Brown and Babcock as being compatible with the return of function for this nerve. Highet also reported seven cases of radial-nerve resection of amounts not exceeding six centimeters, and all patients showed some degree of recovery. The average amount resected in this series was 5.2 centimeters, but this does not include the length of nerve destroyed completely at the time of injury. The length of nerve excised is rather confusing. Table I presents actual measurements of the amount of tissue removed from both segments before healthy fasciculi were reached. It does not include the amount of nerve tissue which was inextricably bound up with the osteoid tissue of the fracture, nor does it indicate the gap between the segments after such excision. Therefore, we have no accurate measurement of the total length of nerve destroyed, nor could we determine any method by which this could be measured accurately. The nerve retracts after being severed; and, when continuity has been restored, the more traction that is applied, the less seems to be the original defect. In all of these cases, an attempt was made to restore normal tension with only moderate flexion of the distal portion of the extremity, and to make up the deficit by bone shortening.

A report by Hoen suggests that the danger in postoperative stretching of a sutured nerve affects particularly the distal fragment. His recent work (reported to the Harvey Cushing Society in October 1946) suggests that good results are obtained when traction has been applied to the proximal fragment only. If this method of dealing with wide gaps proves successful, it will lessen still further the proportion requiring skeletal shortening.

The time saved by the combined procedure in restoring the arm to normal function can be estimated in terms of months. The percentage of normal function which is recovered varies directly with the length of time after injury at which nerve regeneration is attained. As regeneration is delayed, the number and severity of irreversible changes in the nerve and in its end plates increase. The size of the nerve trunk itself is diminished, as shown by Young; but more severe are the changes in the numerous end plates which, although they may function again, are greatly reduced in efficiency [13]. Secondarily, muscle fibrils seriously affected by delayed innervation are gradually encroached upon by interstitial fibrosis and, when re-innervation is postponed for a year or more, cellular changes in the muscles denote the beginning of a degenerating process which progresses steadily to complete disintegration in approximately three years [2]. How long this destruction can be postponed by regular periods of galvanic stimulation is debatable [12]. More definite are the grave effects of prolonged immobilization [18], which is inevitable when injuries of bone and nerve are treated successively rather than concurrently.

Only one patient in this series received a skin graft to effect secondary closure. If oedema was carefully prevented, wounds could be closed under tension not previously thought advisable; but where gross skin loss was present, skin-grafting had to be carried out. The delay which this entailed, however, prolonged the time from injury to healing an

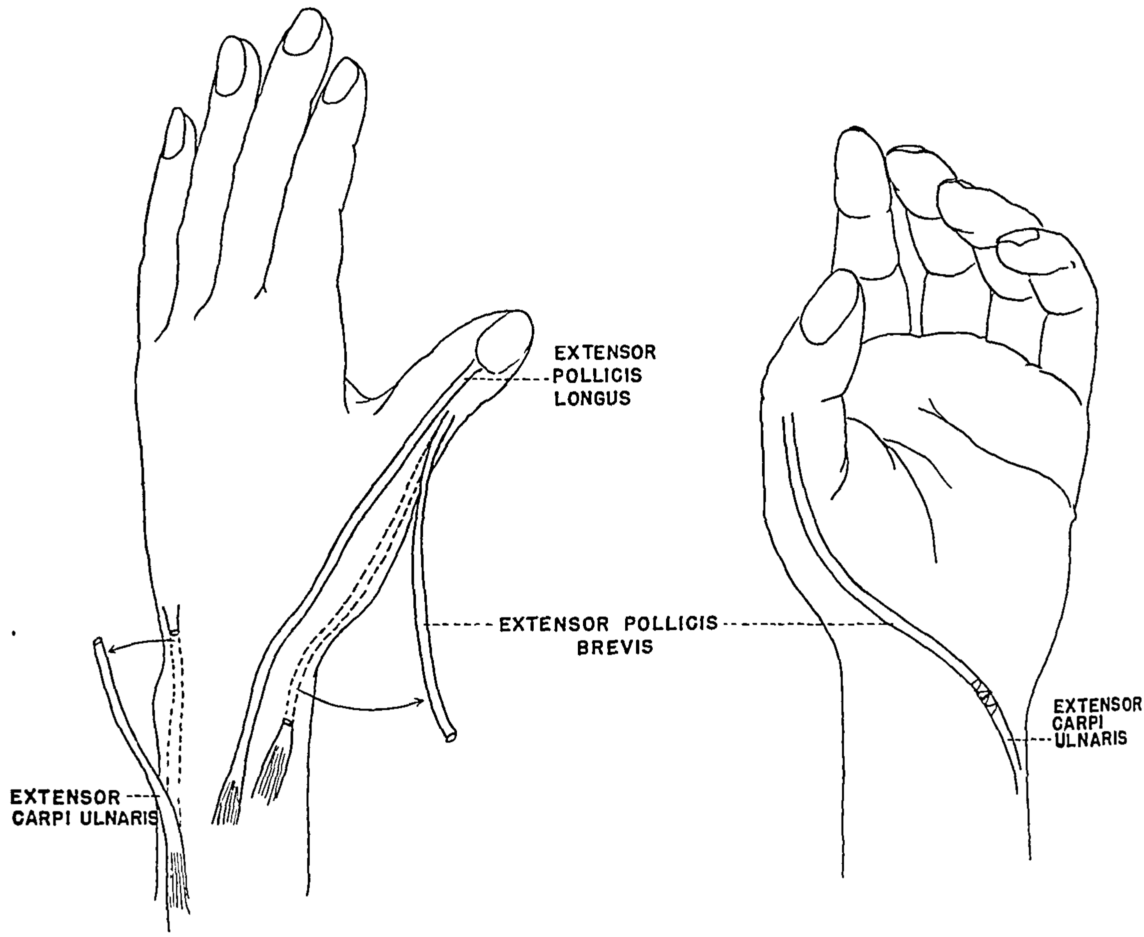

FIG. 3

Diagram showing transfer of extensor carpi ulnaris tendon to serve as the motor element of a tendon transfer to restore opposition to the thumb. In the drawing at the left, the extensor carpi ulnaris tendon has been severed at its insertion, and the extensor pollicis brevis has been cut at its musculotendinous juncture and withdrawn at its insertion into the base of the thumb. In the drawing at the right, the extensor pollicis brevis tendon has been rerouted subcutaneously across the palm, and sutured to the extensor carpi ulnaris tendon at the medial side of the volar aspect of the wrist. A free tendon graft may be substituted for the extensor pollicis brevis tendon, if the latter is not available.

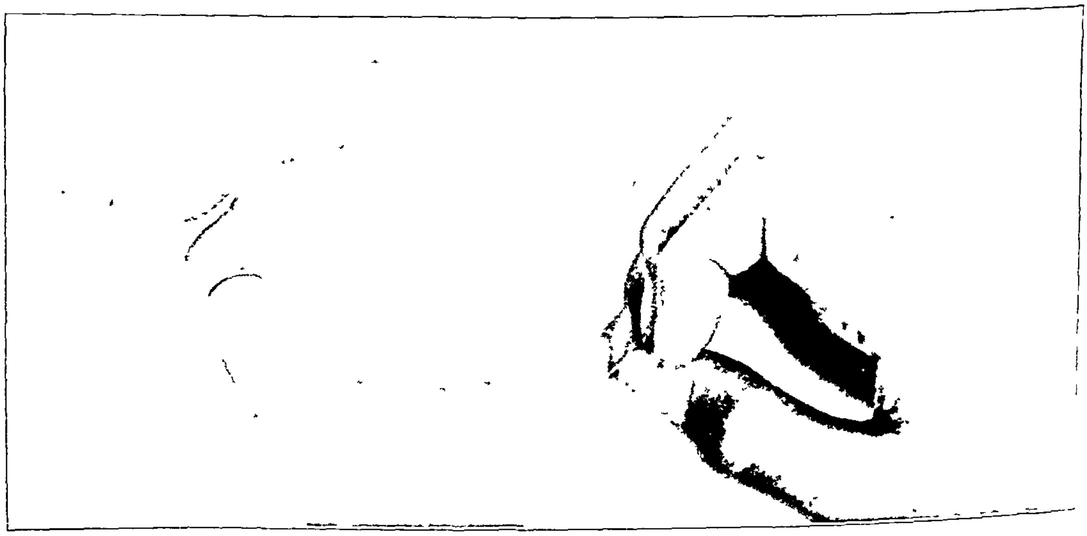

FIG. 4-A FIG. 4-B

Fig. 4-A: Photograph of the right hand of a patient with paralysis of the median and ulnar nerves, showing inability to oppose the thumb to any of the fingers.

Fig. 4-B: Shows the same patient, four weeks after the thumb had been motivated by transfer of the extensor carpi ulnaris tendon.

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TRANSPOSITION OF FINGERS IN SEVERE INJURIES OF THE HAND

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Penetrating wounds of the hand, caused by shell fragments or bullets which enter either the palm or the dorsum of the hand and pass completely through, result in severe damage to bones and soft tissues. Wounds of this nature usually occur in combat areas and, therefore, complete débridement with primary closure cannot be done. Occasionally, secondary closures are carried out. Due to the type of the injury, extensive scarring always occurs along the course of the missile, extending completely through the hand. This scar involves the tendons, nerves, and intrinsic muscles, and is nearly always adherent to the bone. The loss of tendon and nerve function of the finger results in a so-called "dead finger". In some cases the blood supply to the finger is jeopardized, which results in a swollen, cyanotic finger. When an amputation has been performed previously, the flexor tendons are frequently found adherent to the scar, preventing flexion of the remaining fingers. When the finger has not been amputated, the flexor tendons are caught in the scar and will gradually pull the involved finger into a flexed position, thus preventing function of the finger, and inhibiting the function of the remaining fingers. Frequently there is a painful neuroma in the scar which prevents the patient from using the hand, since any light touch causes extreme discomfort.

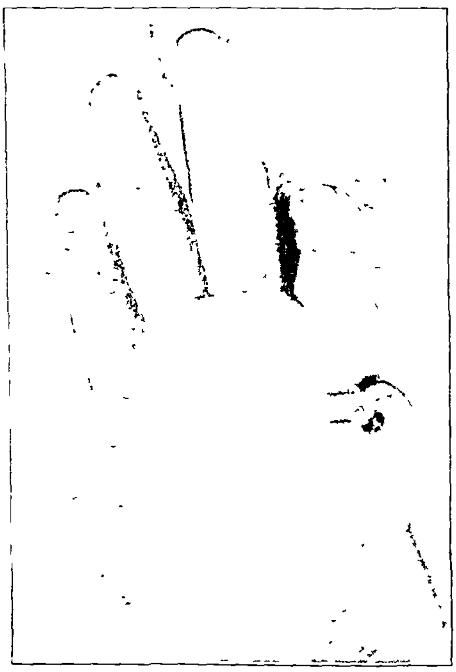

FIG. 1-A

In the reconstruction of the severely damaged hand, the first consideration is complete excision of scar tissue, which leaves a large soft-tissue defect of the hand. The closure of such a defect would require a pedicle flap. The two objectives which guide this reconstruction are to restore the most function and to attain the best appearing hand. In those cases in which the long or the ring finger has been amputated, or in a so-called "dead finger", we have found it advisable to transpose the adjacent finger, together with its metacarpal, thus eliminating the defect and approximating normal, healthy tissue. By transposing the normal metacarpal and finger into the defect which has resulted from the amputation and resection of the scar, the hand is narrowed, but the appearance and function are improved. This places the remaining fingers parallel and prevents the deviation and rotation of the adjacent fingers into the defect, as happens when a finger and a portion of the metacarpal are amputated. When the damage involves the bony structures and tendons to the ring or long fingers, we resect the scar tissue and severely damaged metacarpal down to the base. If the defect involves the ring finger, osteotomy is performed on the fifth metacarpal near its base, and the fifth metacarpal is transposed to the base of the fourth metacarpal. If the long finger is involved, osteotomy is performed on the second metacarpal which is then transposed to the base of the third.

Occasionally it is advisable to transpose the index finger to the first metacarpal to

*See note, page 1004.

to Ollerenshaw's concept. Herzmark reported a case of bilateral "giant" external menisci, and mentioned mucoid degeneration in one of them. Meekison recorded one case, and Ober two instances, of cyst formation in malformed lateral menisci. Ollerenshaw, in recording the only instance which he observed of cyst arising from the medial or free border of a lateral meniscus, described the cartilage as being broad in structure (Fig. 2). He pointed out that the lateral meniscus is by far the most frequent site of cyst formation (as observed in thirty-six of his own forty-two cases), although it is less apt to become injured. Of the fifty or more malformed menisci which had been reported up to 1941, only two involved the medial meniscus.

One of the authors (J. K.), in reporting nineteen cases of cyst of the lateral meniscus,

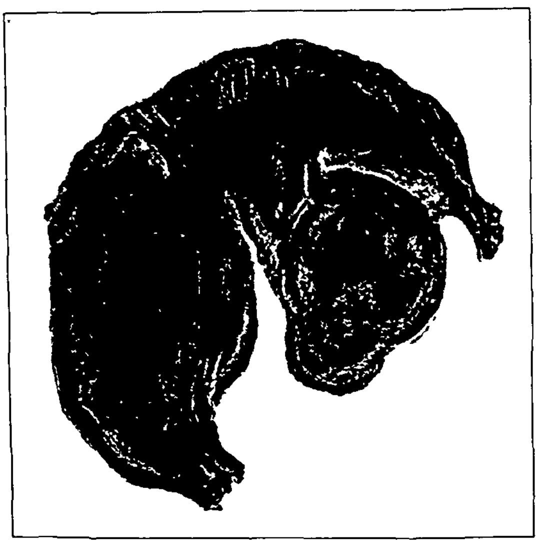

FIG. 2

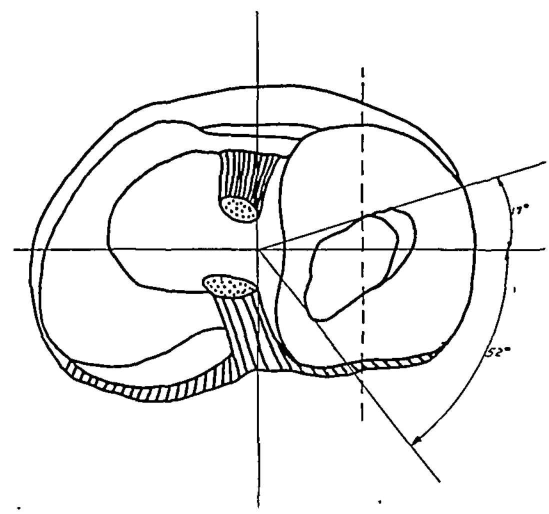

FIG. 3

Fig. 2: Malformed lateral meniscus with cyst formation at its medial or free border (redrawn from Ollerenshaw). (Reproduced, by permission, from *The British Journal of Surgery*, 23: 278, 1935.)

Fig. 3: Drawing represents the upper surface of the tibia and discoid cartilage in the present case. The area of attrition subtended an angle of about 70 degrees, and was presumed to have been caused by coaxial movements between the fixed lateral cartilage and the femoral condyle,—the anterior half by the pinching stresses in the position of extension, and the posterior half by the rotational component of movement.

noted that three were associated with variable degrees of malformation, with no evidence of trauma. In one, a boy of fifteen years, there was an enlarged but annular type of cartilage. In another (a case of Steindler's which was included in that series), both lateral menisci were discoid, with cystic changes in one of them. In the third, a male of thirty-three years, there was a comma-shaped malformation in the anterior half, with cystic changes therein. In the case reported here, unfortunately, the microscopic examination was confined to the eroded area alone, and no cystic changes were described there. It may be that the cyst found at operation was wholly parameniscal. However, it would seem justifiable to conclude that at least some cysts are congenital in origin, in so far as compression of a malformed cartilage would accelerate a secretory response in cells which had retained some of their embryonal character.

Ordinarily the clinical symptoms of an uncomplicated malformed (biconcave) lateral meniscus are due to malalignment of the joint surfaces by this interposed structure. When this cartilage is attached loosely, it slips and causes reposition of the condyles. This is accompanied by an audible and palpable snap or thud ("trigger" knee). What happens when the cartilage is firmly attached was illustrated in the present case. Since it was practically fixed to the tibia, the grinding and twisting action of the joint impressed itself upon the fixed interposed discoid cartilage during the automatic coaxial excursions which are known to occur in the knee (Fig. 3).

Case 2. Patient was injured by bullet passing through the right hand; bullet entered the palm with exit on the dorsum of the hand, causing tremendous scarring. The middle finger was amputated and the index finger was transposed to the position of the middle finger.

Fig. 2-A: Original palmar view.

Fig. 2-B: Dorsal view upon admission.

Fig. 2-C: Postoperative roentgenograms.

Fig. 2-D: Final palmar view.

Fig. 2-E: Final dorsal view.

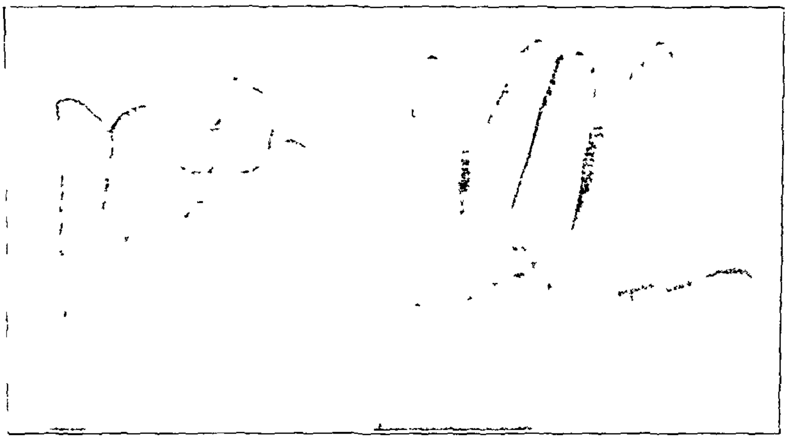

Fig. 2-A Fig. 2-B

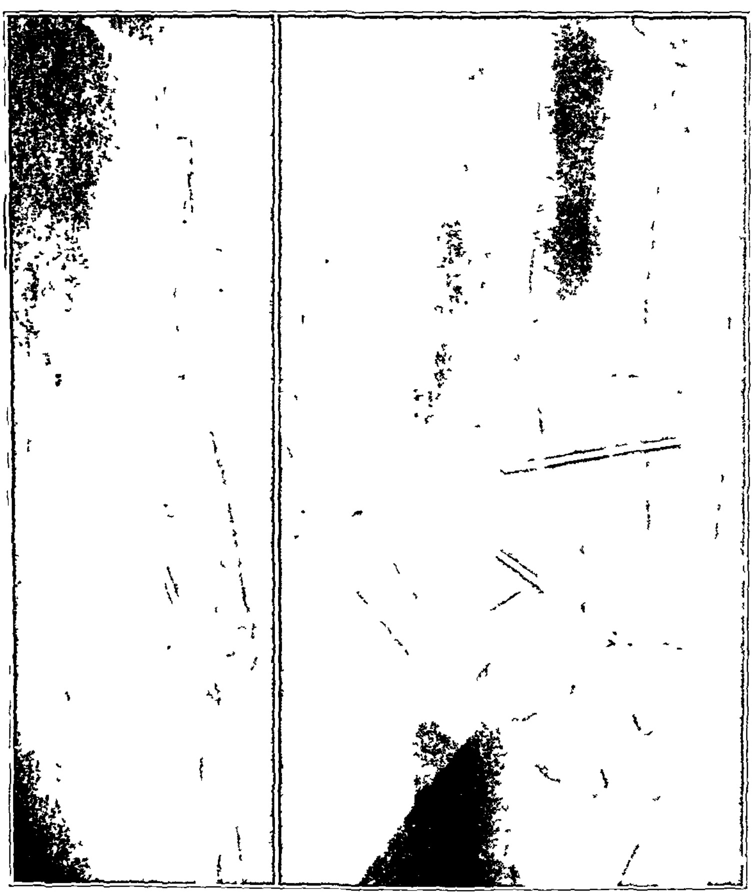

Fig. 2-C

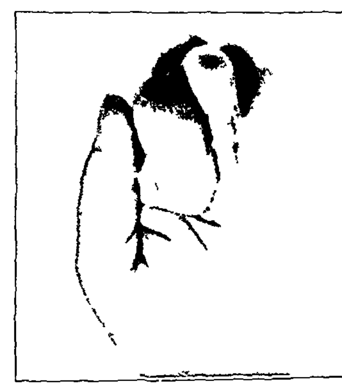

Fig. 2-D

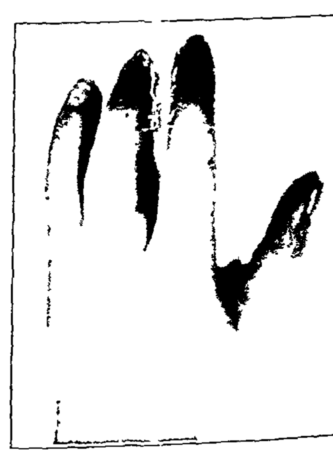

Fig. 2-E

carried with it. This necessitates splitting the digital nerve slip of the adjacent sides of the index and middle fingers well up into the base of the hand, as well as freeing and dividing the vessels necessary to allow the transposition. The tendon control of the index finger is preserved and maintained to control flexion and extension of the newly formed thumb. This results in a thumb which will oppose the fingers, have normal sensation, and have flexion and extension control, as well as the ability to grasp large or small articles.

Dial reported a case in which he lengthened the thumb with a tube graft, stabilizing it with a bone graft. Albee applied a tube and a bone graft to the hand stump, so that the remaining thumb would oppose a stable stub finger. Reports have appeared in the Italian literature on phalangization of the first metacarpal. In the above cases, the first metacarpal was kept in its position and the cleft between the first and second metacarpals was deepened. Nuzzi presented examples of this type of procedure and stated it had been

THE TRANSFER OF WRIST EXTENSOR MUSCLES TO RESTORE OR REINFORCE FLEXION POWER OF THE FINGERS AND OPPOSITION OF THE THUMB *

BY GEORGE S. PHALEN, M.D., CLEVELAND, OHIO, AND
RICHARD C. MILLER, M.D., KANSAS CITY, MISSOURI

When a surgeon is called upon to restore active motion to a paralyzed hand, he must take great care in determining the type of operative procedure which will produce the best result. Each case is an individual problem. The surgeon must examine the hand carefully to ascertain, first of all, what necessary motor functions are lacking; and then he must decide what active muscles are available for transfer into the paralyzed muscles.

The flexor carpi radialis, the flexor carpi ulnaris, and the palmaris longus muscles are frequently employed to restore or reinforce flexion power of the fingers and opposition of the thumb. The wrist and finger extensor tendons have been employed much less commonly for this purpose.

On the Hand Service of an Army General Hospital, the authors encountered patients with loss or diminution of flexion power in the wrist and fingers secondary to injury of the brachial plexus, combined injury of the median and ulnar nerves, or actual destruction of the substance of the flexor muscles. The restoration of flexion power to these crippled hands presented a difficult problem.

Probably the two most common methods of treating such cases are arthrodesis of the wrist with transfer of the three wrist extensors, or tenodesis of the flexor tendons to obtain automatic flexion of the fingers when the wrist is extended. The authors believed that the mobility of the wrist joint might be retained and the flexor power of the fingers restored by a transfer of one of the radial extensor muscles of the wrist into the flexor tendons of the fingers.

In an occasional case of incomplete palsy of the median and ulnar nerves, the wrist flexors were found to be strong and the finger flexors were weak. In these cases, when it became obvious that there would be no further return of nerve function, we had been using the flexor carpi radialis to reinforce the finger flexors; but, after observing some of the end results of wrist extensor transfers in cases in which no wrist flexors were available, we concluded that the extensor carpi radialis longus or the extensor carpi radialis brevis was a better muscle to reinforce the finger flexors than the flexor carpi radialis. Extension of the wrist and flexion of the fingers are more of an associated movement than flexion of the wrist and flexion of the fingers. It was apparent in these cases that much more power of flexion was imparted to the fingers by transfer of the extensor carpi radialis than by transfer of the flexor carpi radialis.

The authors have performed this type of tendon transfer in eight cases,—four cases of injury of the median and ulnar nerves or brachial-plexus palsy, involving primarily the median and ulnar nerves, and four cases of irreparable muscle damage, involving the flexor muscles in the forearm.

In the latter group—those with muscle damage—one patient with only a few degrees of flexion power in the index finger and none in the remaining fingers, but with a normally supple and mobile hand, obtained an excellent result, with ability to make a strong fist. The long flexor muscle of the thumb had not been damaged seriously.

Two patients with much less supple and mobile hands obtained considerable improvement. When last seen (approximately three months after operation) they still could not

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1947.

FIG. 4-A

FIG. 4-B

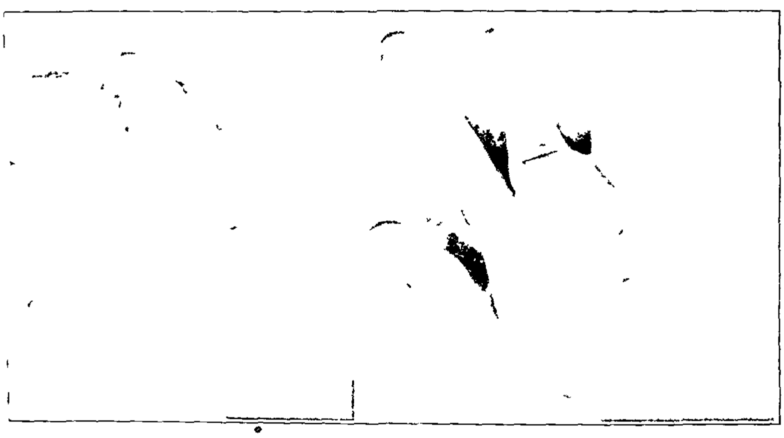

FIG 4-C FIG. 4-D

CASE 4. Shell-fragment wound of the hand, with loss of ring finger and complete destruction of the metacarpophalangeal joint of the middle finger. Patient was treated by local flap to the dorsum of the hand, arthroplasty to the metacarpophalangeal joint of the middle finger, excision of the fourth metacarpal, and transposition of the middle finger to the position of the ring finger.

Fig. 4-A: Original roentgenograms of the hand.

Fig. 4-B: Final roentgenograms.

Figs. 4-C and 4-D: Final views of the hand.

[Figs. 4-A and 4-B reproduced by permission of The Yorke Publishing Co., Inc. (Snedecor, S. T.: Bone Surgery of the Hand. *The American Journal of Surgery*, Vol. 72, p. 369, Sept. 1946).]

the operation. Tonnini converted the index finger to act as the thumb. The method which he used was somewhat similar to that here described; he attached the tendons of the lost thumb for the motor power, but did not shorten the converted digit. We felt that this was undesirable and we retained the motor power of the converted finger.

TRANSPOSITION OF INDEX FINGER TO REPLACE THUMB

The operative technique for the conversion of the index finger to the thumb was carried out in two stages. As seen by the roentgenograms, the thumb was missing near the metacarpophalangeal joint. It so happened that there was also considerable loss of bone substance and scarring along the second metacarpal.

In the first stage of the operation, a dorsal approach was made, and the scar tissue was removed. The distal portion of the second metacarpal was excised, as well as the articular surface and one-half inch of the proximal phalanx of the index finger. The transverse metacarpal ligament was sectioned, and the index finger was freed so that it would retract almost two inches, care being taken to preserve the arteries and the nerves. The first metacarpal was shortened about one-half to three-quarters of an inch, and, by rotating and retracting the index finger, we were able to bring the first metacarpal and the proximal portion of the proximal phalanx of the index finger in contact. They were fixed in this position with stainless-steel wire. At this point, attention was directed to securing the proper rotation of the index finger to give opposition. The wound was then closed, and a period of six weeks intervened before further surgery was carried out.

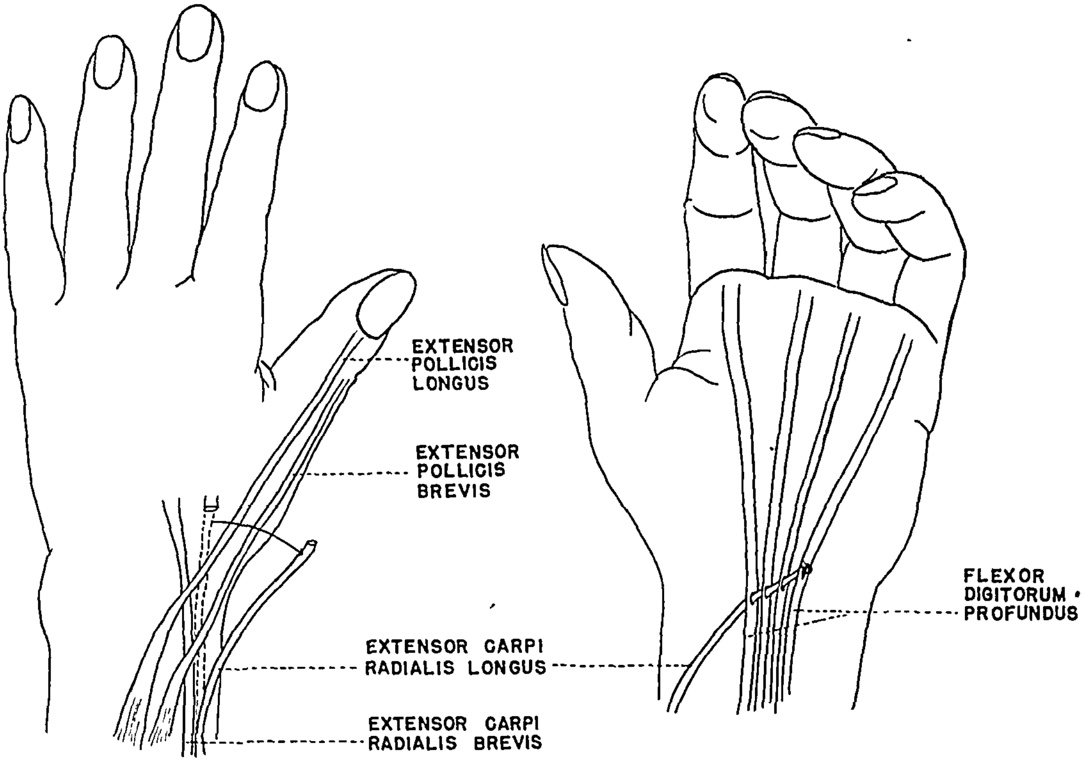

FIG. 2

Diagram showing transfer of extensor carpi radialis longus tendon into flexor digitorum profundus tendons. The extensor tendon is severed close to its insertion, as shown at the left, and is then freed well up into the forearm, rerouted subcutaneously onto the volar aspect of the wrist (as shown at right), and inserted into the flexor profundus.

of the absence of joint limitation and scarring, so frequently associated with the muscle injury. However, two patients had imbalance from intrinsic-muscle paralysis, and extension of the distal joints of the fingers was unsatisfactory.

In these transfers, the extensor carpi radialis longus was used most frequently, although in one case the extensor carpi radialis brevis was employed. The tendon was severed at its insertion, freed well up into the forearm, and then rerouted subcutaneously to the volar surface of the wrist and inserted through buttonholes in the flexor profundus group (Fig. 2). In one case, the extensor carpi radialis brevis was inserted into the flexor sublimus group, and the end result was very satisfactory. In some cases, the transferred tendon was passed beneath, instead of superficial to, the flexor carpi radialis tendon. Little difference was observed between these two methods of transfer. It was felt, however, that it was important to make the transferred tendon pull in as direct a line as possible.

The authors have also employed the extensor carpi ulnaris tendon as the motor element of a tendon transfer to restore opposition to the thumb in seven cases in which no flexor tendons were available for the transfer. In all of these cases, some power was present in the flexor muscles of the fingers; but these muscles were so weak that the authors did not feel justified in weakening further the flexion power of a finger by sacrificing a sublimus tendon for the transfer. No wrist flexor tendons were available for transfer in any of the cases.

The extensor carpi ulnaris did not make so effective an opponens transfer as a flexor muscle would have done, but the end results in these badly crippled hands were quite satisfactory. A thumb, lying useless by the side of the hand, was given the ability to rotate across the palm and to oppose the index finger, middle finger, and ring finger; and, in at least half the cases, the thumb could also touch the tip of the little finger.

In all of the cases in this series, the tendon of the extensor pollicis brevis was severed at its musculotendinous juncture, transferred subcutaneously across the thenar eminence, and sutured to the cut end of the extensor carpi ulnaris, which had previously been severed

two Kirschner wires, put through obliquely into the adjacent metacarpals. When the wires are inserted, great care is taken to have the rotation of the metacarpal exactly correct, thus allowing the metacarpophalangeal joint to move in the proper plane. The metacarpal ligament is also repaired.

The hand is put in a firm pressure dressing and supported for a period of three weeks. At the end of that period, active motion, which includes physiotherapy and occupational therapy, is instituted. At the end of six or seven weeks, the Kirschner wires are removed.

The procedure of collapsing the hand narrows it moderately, but not enough to weaken the hand to any extent. Any weakness which may result from narrowing the hand is far overshadowed by the advantages gained in having the fingers approximated so that they will function as a unit. Further surgical procedures may be indicated, at some later date, to restore complete balance and function to the hand.

SUMMARY

1. The procedure described for reconstruction of a useful hand after loss of a central finger or the thumb has been carried out twenty-seven times with slight modification. Various tendon transplantations and grafts were frequently done at the same time. The method consists in transposing the adjacent finger and metacarpal into the defect, thus restoring the parallel alignment of the remaining fingers. In loss of the ring finger, the fifth metacarpal is transposed to the base of the fourth metacarpal. When the long finger is missing, the second metacarpal is transposed to the base of the third metacarpal.

2. The method described for reconstruction of the thumb after amputation consists in transposing the index finger to the first metacarpal, after shortening the index finger to the proper length; then rotating it to the proper position for opposition, and maintaining its blood and nerve supply and tendon control.

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Note: Dr. Walter C. Graham, Dr. J. Barrett Brown, and Dr. Bradford Cannon have returned to civilian practice. Their addresses will be found on page 45 (Advertising).

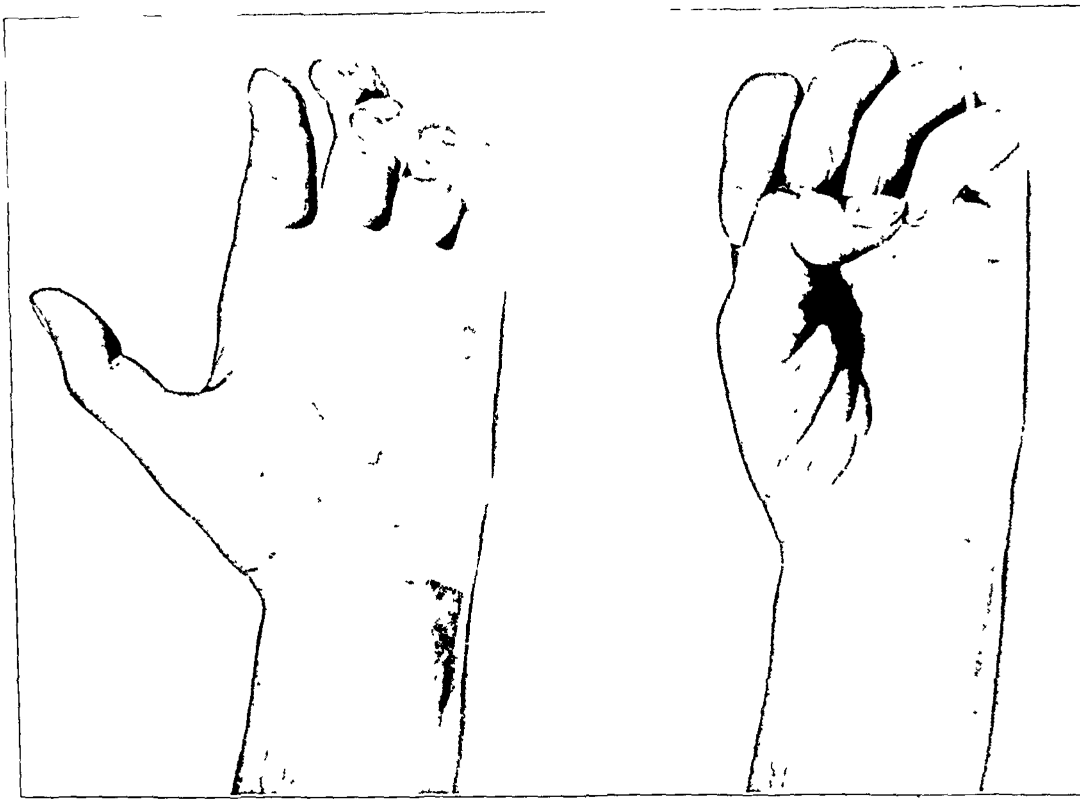

FIG. 5-A FIG. 5-B

Showing the left hand of a patient with a brachial-plexus injury, involving primarily the median and ulnar nerves. Fig. 5-A shows extension and Fig. 5-B shows opposition of the thumb, two months after transfer of the extensor carpi ulnaris tendon. Function in this hand was greatly improved by the transfer. Prior to operation, the thumb could neither be adducted across the palm nor opposed to any of the fingers.

at its insertion and transferred subcutaneously to the medial side of the volar aspect of the wrist (Fig 3). No attempt was made to create a pulley at the pisiform bone, as is usually done when a flexor muscle is used as the motor power in such a transfer. Care was taken to keep the extensor carpi ulnaris tendon in the subcutaneous tissue, in order to avoid any adherence of the tendon to the underlying ulna.

One of these patients was an Army sergeant who sustained multiple saber cuts on his right forearm, involving the median and ulnar nerves. The nerves were sutured, but there was no evidence of any return of function in the intrinsic muscles of the hand after eight months. There was profound disability in the hand; the patient was unable to touch the tip of his thumb to the tip of any finger (Fig. 4-A). Because of the weakness of the finger flexors, it was thought not advisable to sacrifice one of the sublimus tendons to act as the motor power in the transfer of the thumb opponens; therefore the extensor carpi ulnaris tendon was used instead. Four weeks after the transfer of the extensor carpi ulnaris, the patient was able to oppose the thumb to the index finger, middle finger, and ring finger; after another month, he was able to oppose the thumb to all of his fingers.

A similar case is illustrated by Figures 5-A and 5-B. This Army private sustained a brachial-plexus injury, with involvement primarily of the median and ulnar nerves. The thumb remained useless at the side of the palm; it could neither be adducted across the palm nor opposed to the tip of any of the fingers. The flexor carpi radialis and the flexor carpi ulnaris were not functioning, and there was no palmaris longus tendon. There was some power of flexion in all of the fingers and the thumb, but this power was not sufficient to warrant sacrificing one of the flexor sublimus tendons to serve as the motor power for an opponens transfer to the thumb. Consequently, the extensor carpi ulnaris was employed; and the end result was very satisfactory. The patient was able to oppose his thumb to all of his fingers.

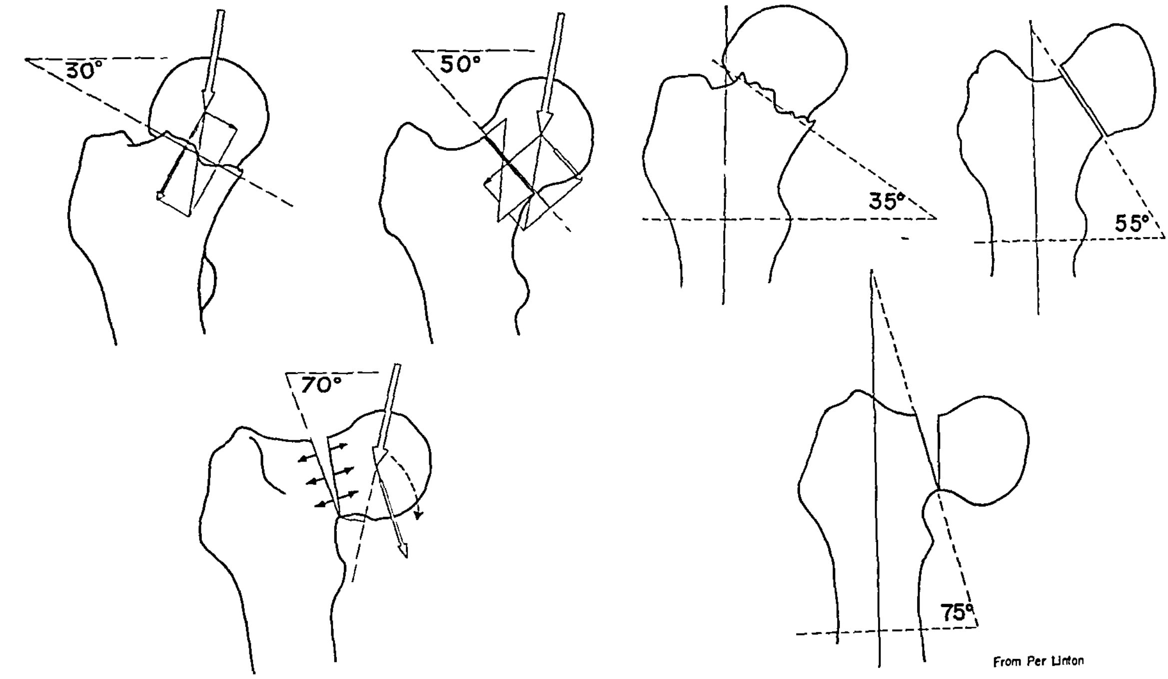

FIG. 1 FIG. 2

Mechanical factors in fractures of the neck of the femur.

Fig. 1: Pauwels' analysis of the plane of fracture. (From Friedrich Pauwels.)

Fig. 2: Linton's analysis of the plane of fracture.

To appraise the mechanical factor, Pauwels made a careful mathematical analysis of the mechanical stresses on the fracture plane in fractures of the femoral neck, occurring at different angles. He has classified these fractures into three groups, according to the angle between the line of the fracture and the horizontal line running through the anterior-superior iliac spine (Fig. 1). If this angle is less than 30 degrees, the fracture is impacting, and will unite soundly with any type of treatment. If the angle is between 30 and 70 degrees, there is less impaction and some shearing strain; the fracture will not unite, unless this shearing force is overcome by internal fixation. If the angle is between 70 and 90 degrees, the fracture line is so nearly vertical, and the effect of shearing stress is so great, that non-union may be anticipated, regardless of whether a Smith-Petersen nail, multiple pins, or the lag screw is used as the method of internal fixation.

Linton, in an analysis of 365 cases of fracture of the femoral neck (Fig. 2), agreed essentially with Pauwels' analysis of the mechanical factors, although he measured the angle of the fracture line in relation to the shaft of the femur, rather than in relation to the horizontal line through the anterior-superior iliac spine. He believed that this furnished a more accurate measurement, since the horizontal line is not always easy to estimate, because, in most cases, a roentgenogram of only one hip is available for study; and the pelvis is, therefore, insufficiently shown to make accurate calculations. Linton stressed the importance of taking the roentgenograms with the limb in internal rotation, in order to procure a free projection of the neck. His method yields angles about 5 to 7 degrees greater than Pauwels', but the results are relatively the same. The author favors Linton's method of calculation as being more accurate, since it is not affected by the adduction or abduction of the limb.

Study of end results after various procedures of osteotomy would seem to indicate that one of the principal difficulties encountered is lack of definite control over the head of the femur and the upper trochanteric segment, and their proper placement, when the shaft of the femur is displaced medially. In many instances, the head of the femur is not rotated sufficiently, and the fragments are not correctly placed to facilitate bony union and repair. Reliance has been placed entirely on the impaction of the fragments

replace the amputated thumb. How crippling is the loss of the thumb to the function of the hand is well known; to replace it with a digit which has sensation and muscle control is an extremely valuable procedure. In transferring the index finger to the thumb, many points must be considered. Probably the first in importance is the length of the digit. If it is to function as a thumb, it should be shortened from one to two inches, so that in the opposed position, with the fingers partially flexed, it will not extend beyond the ends of the fingers. Also, the finger must be rotated almost 90 degrees and must have sufficient cleft to allow the opposed position and abduction.

If the index finger is to function as a thumb, the nerve and blood supply must be

Fig. 1-B Fig. 1-C

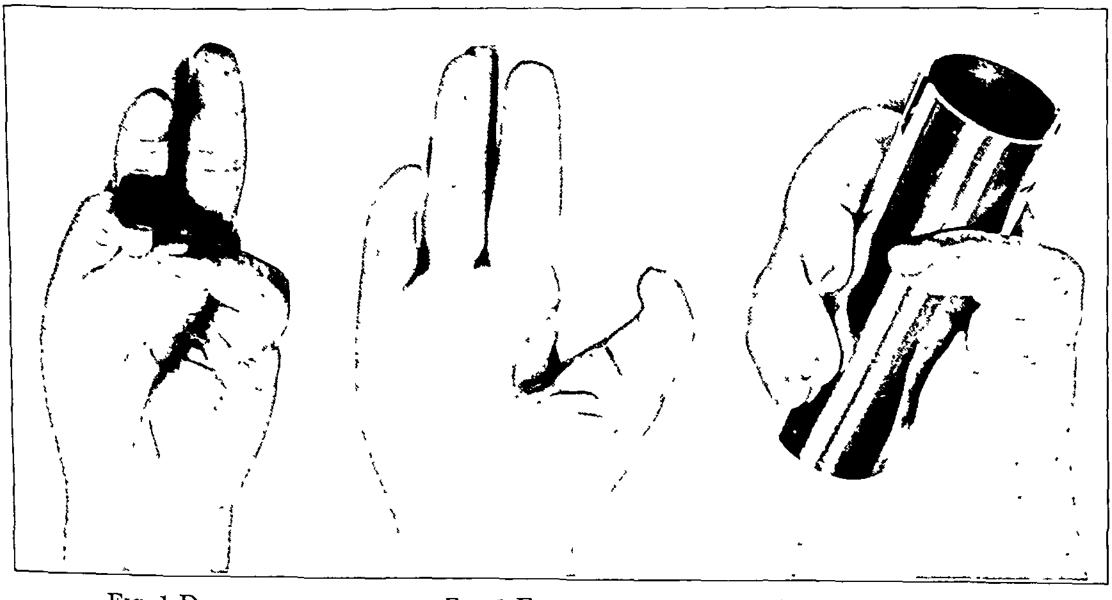

Fig. 1-D Fig. 1-E Fig. 1-F

Case 1. Patient was struck on right hand with shell fragments, losing the thumb at the metacarpophalangeal joint. There was severe comminution with loss of bone substance of the second metacarpal. Treatment included transplanting the index finger to replace the missing thumb, fixing the finger to the first metacarpal, and filling in defect with a local flap and split-thickness skin graft.

Figs. 1-A and 1-B: Photograph and roentgenogram of the hand upon admission.

Fig. 1-C: Roentgenograms of hand after transposition of index finger.

Figs. 1-D, 1-E, and 1-F: Final appearance of the hand after rehabilitation.

segment, and that this rotation should be accurately and consistently controlled. This osteotomy, with its mechanical advantages, should be combined with bone-grafting to stimulate osteogenesis, in cases in which this added factor would prove beneficial. The operation should be one which requires a minimum of dissection and of interference with the remaining blood supply to the head and neck of the femur. Shortening in the affected limb should be overcome. In the postoperative treatment, fixation in a plaster cast should be eliminated.

To fulfill these requirements for an ideal procedure for treatment of ununited fracture of the femoral neck, the following technique was planned: It was decided that the trochanteric portion and the head of the femur might be transfixed with a blade plate, penetrating from the lateral prominence of the trochanter into the lower half of the head, to assure accurate control of the head and the trochanteric segment. In anticipation of this 60-degree rotation, the shaft of the blade plate should extend outward at an angle of 60 degrees to the long axis of the femur, so that proper placement of the plate might be readily accomplished after the osteotomy and necessary rotation had been completed (Fig. 5).

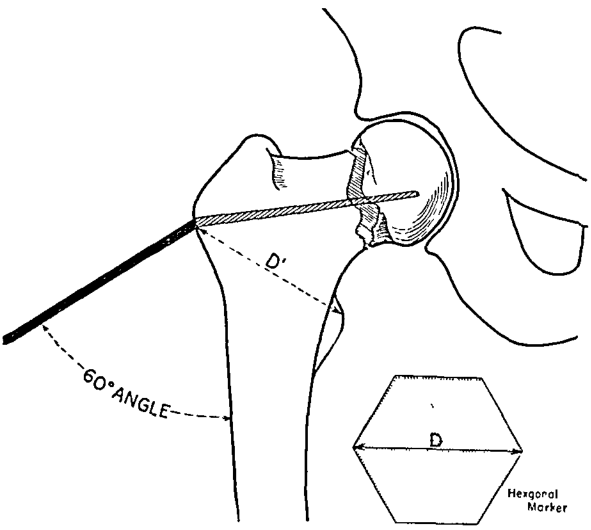

Fig. 5

Transfixion of upper segments with plate at 60 degrees. Drawing shows the method of fixation, the angle of the blade plate, and the estimation of the diameter of the chisel used for marking the site of the osteotomy.

In planning the operation, cognizance was taken of the importance of preserving the remaining blood supply to the head and the trochanteric segment [20, 36, 37]. In exposure of the anterior surface of the intertrochanteric region, the muscles and vessels should be retracted medially, so as to preserve the vascular supply to this region. Osteotomy should then be accomplished with a minimum of interference with the remaining blood supply.

In order to achieve a rotation of 60 degrees that could be accurately and consistently controlled, it was decided that the osteotomy should be made along two sides of what would be a regular hexagon; the fragments could then be rotated by one segment. Hence, it

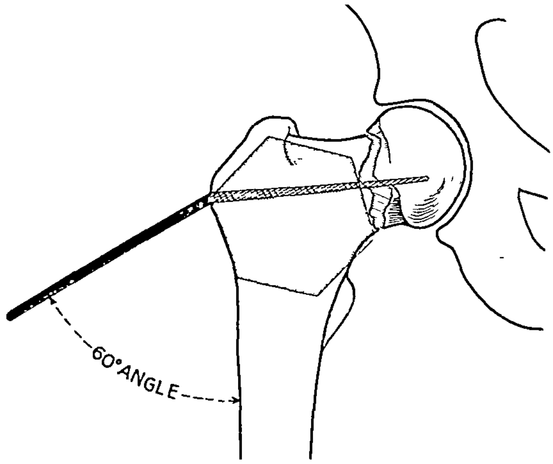

Fig. 6

Drawing showing placement of hexagonal marker to determine the site of osteotomy.

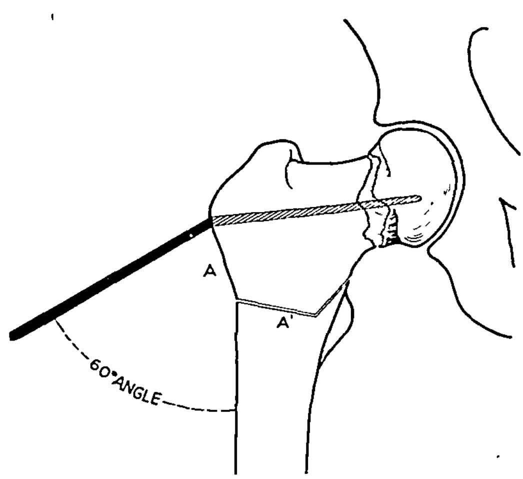

Fig. 7

Drawing showing the osteotomy site.

used by Cipollino and Guermonprez-Klapp and others. Rinaldo's procedure was of a similar nature.

The conversion of another digit to act as a thumb is an operation which has been performed many times. Joyce reported two cases in which the ring finger from the opposite hand was transposed to act as a thumb. In these cases, no attempt was made to suture the nerve, but Joyce stated that there was a return of some sensation. He reported no motion in the two distal joints. Dunlop suggested a method similar to the one here described, but he had not performed

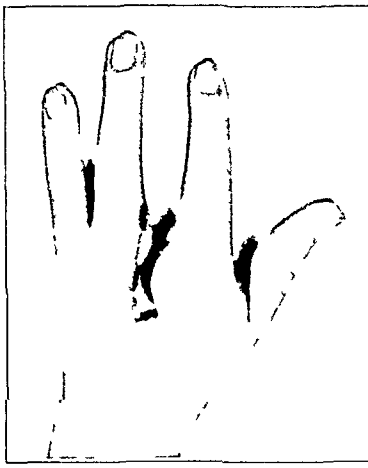

Fig. 3-A

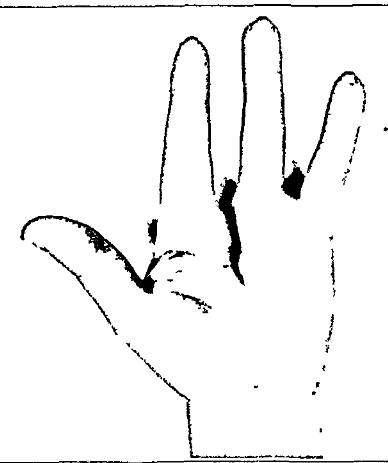

Fig. 3-B

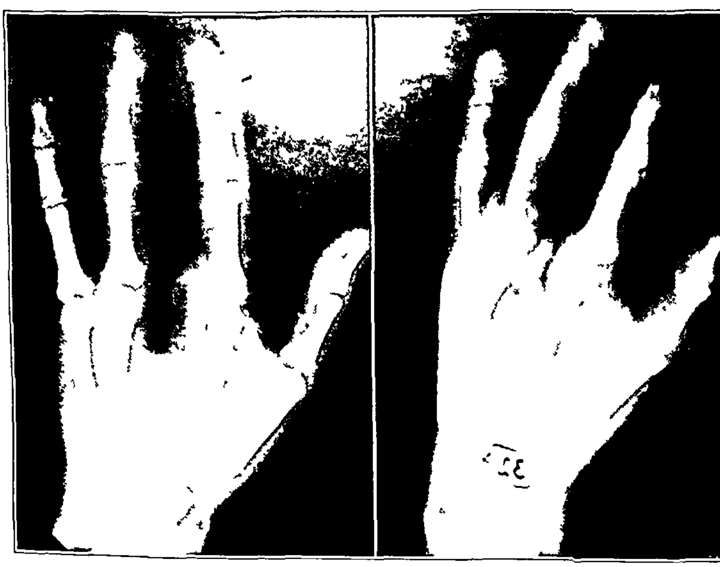

Fig. 3-C

Fig. 3-D

Case 3. Patient was injured when a rifle bullet passed through his left hand, tearing out the middle finger, and leaving a large cleft in the hand He was treated by the *transposition of the ring finger to fill in the defect caused by the loss of the middle finger.*

Fig. 3-A: Original dorsal view of the hand

Fig. 3-B: Volar view.

Fig. 3-C: Roentgenograms upon admission

Fig. 3-D: Postoperative roentgenogram.

Fig 3-E: Final palmar view.

Fig. 3-F: Dorsal view.

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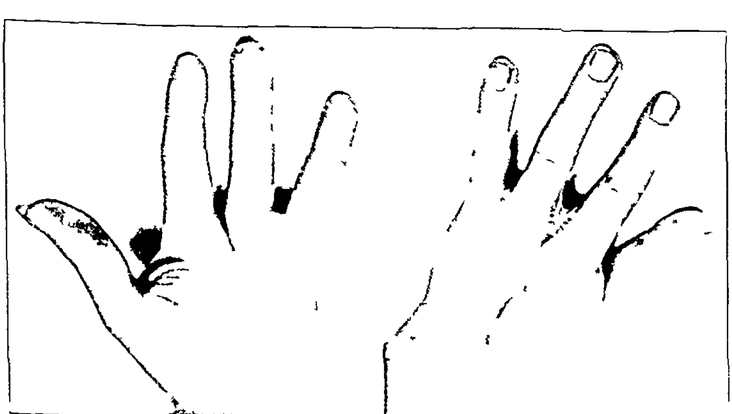

Fig. 3-E

Fig. 10

Fig. 11

Fig. 10: Preoperative roentgenogram for estimation of actual size of the bone.
Fig. 11: Roentgenogram showing guide wire in place for estimation of position and length of blade plate.

At the time of operation, the patient is placed on the table so that roentgenograms, both anteroposterior and lateral, of the hip are easily made. To accomplish better control of rotation, the limbs are fixed in stirrups with the knees bent. A preliminary roentgenogram is made, so that traction, abduction, and rotation can be adjusted to secure the optimal position.

After the proper preparation and anaesthetization of the patient (with pentothal and inhalation of nitrous oxide and oxygen), an incision, seven or eight inches long, is made on the lateral aspect of the thigh, extending downward from the prominence of the greater trochanter. The outer surface of the bone is exposed subperiosteally, and a bed is prepared for the reception of the blade plate after the osteotomy has been completed. Then, a Smith-Petersen incision is made, as in acetabuloplasty, which exposes the hip joint from the front. The rectus femoris is reflected downward, which allows full exposure of the anterior surface of the femur. The joint capsule is opened, and the incision is carried

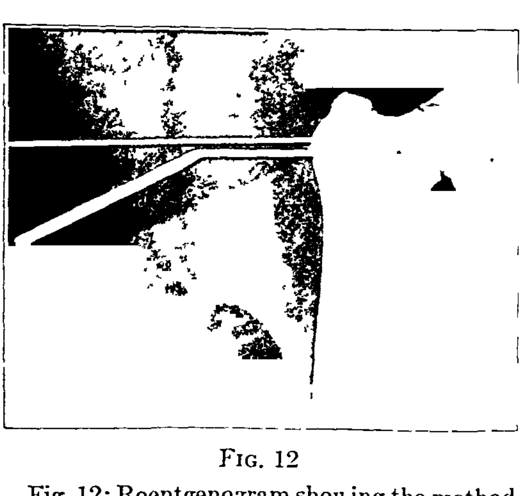

Fig. 12

Fig. 12: Roentgenogram showing the method of determining angulation of the blade plate with a 60-degree protractor.

Fig. 13

Fig. 13: Roentgenogram showing insertion of blade plate into the head of the femur.

Fig. 5-A

Fig. 5-B

Fig. 5-C

Case 5. Rifle bullet through the palm of the hand caused great loss of soft tissue and bone substance of the ring finger. Treatment included excision of scar, amputation of the ring finger, and the transplanting of the little finger to the stump of the fourth metacarpal.

Fig. 5-A: View of the hand before surgery.
Fig. 5-B: Original roentgenogram of hand.
Fig. 5-C: Final roentgenogram of hand.
Fig. 5-D: Final view of the hand.
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Fig. 5-D

At the second stage, the division was made between the index and middle fingers; the incision extended from the base of the palm to the base of the metacarpals dorsally. A dorsal flap was raised to fill the base of the cleft. The vessels anastomosing between the middle and index fingers were freed, leaving the arteries and blood supply to the index finger. The cutaneous nerve branches to the index finger were freed well into the base of the hand. The proximal pulley for the flexor tendon of the index finger was completely excised to free the tendons. Dorsally, the extensor tendons to the index finger were rerouted to the radial side of the wrist so that their direction of pull would simulate that of the extensors of the thumb. The remaining exposed surface was then covered with a split-thickness skin graft, taken from the thigh. In the process of dividing the index and middle fingers, the intrinsic muscles were left with the middle finger, so that they would act in a normal manner. The abductors and adductors of the thumb were attached to the converted index finger and thus had their normal function and action. This new thumb was held in a position of abduction and opposition for a period of three weeks, followed by a period of occupation and rehabilitation

TRANSPOSITION TO REPLACE CENTRAL FINGER

To a great extent the line of incision must be controlled by the scar tissue which is present on the dorsal and palmar surfaces of the hand. It is frequently necessary to curve the incision in order not to jeopardize the remaining soft tissue. In the palm of the hand, it is very important to avoid straight incisions, as they tend to cause contracting scars.

If the so-called "dead finger" still remains, it is amputated down to the base of the metacarpal, leaving about three-eighths of an inch of the base. All adherent tendons, neuromata, and damaged muscle tissue are excised completely. Osteotomy of the metacarpal of the finger which is being transposed is then performed at the same level, and the metacarpal is moved centrally over the base of the amputated metacarpal with its intrinsic muscle still attached. The transposed metacarpal is held in its new position by

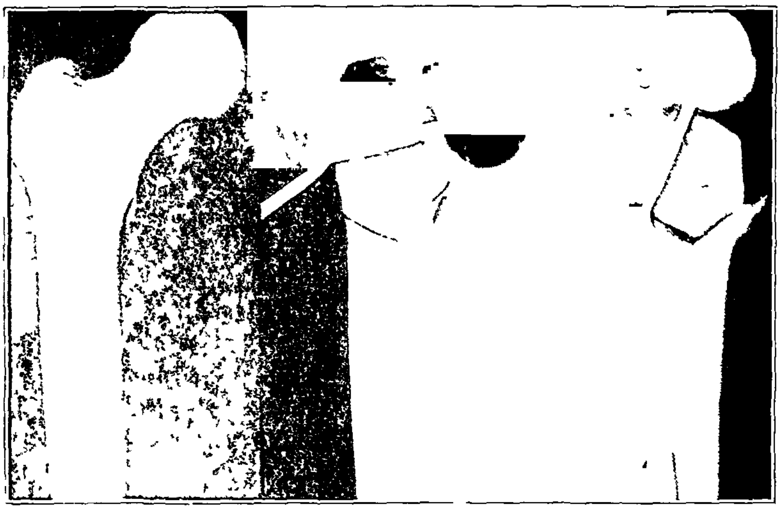

FIG. 15-A

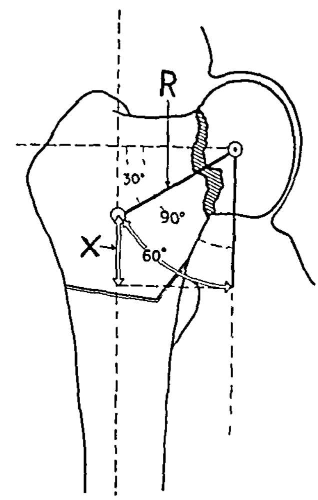

FIG. 15-B

Fig. 15-A: Roentgenogram of femur with ununited fracture and moderate varus deformity, showing equalization of limb length procured by rotation osteotomy.

Fig. 15-B: Moderate varus position with rotation of 60 degrees. Drawing of case shown in Fig. 15-A to show calculation of equalization of limb length.

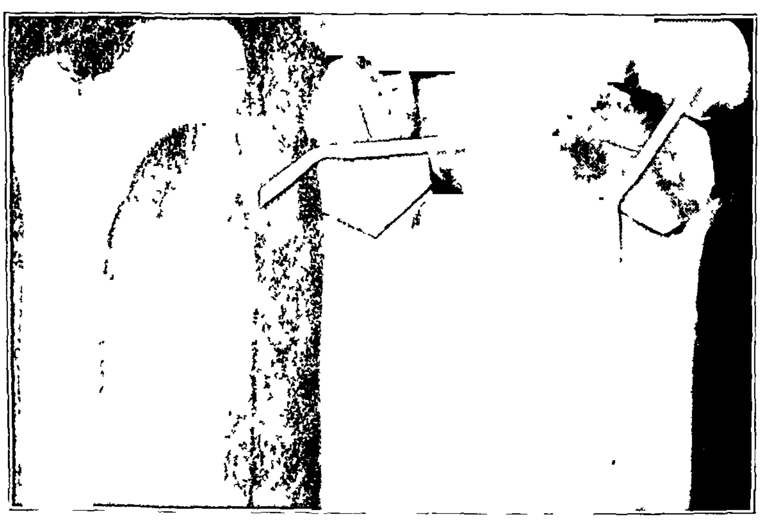

FIG. 16-A

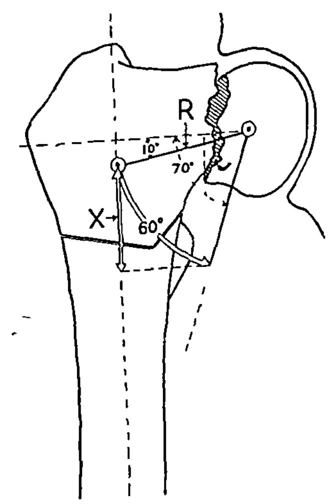

FIG. 16-B

Fig 16-A: Roentgenogram of femur with ununited fracture and extreme varus deformity, showing equalization of limb length procured by rotation osteotomy.

Fig. 16-B. Marked varus position with rotation of 60 degrees. Drawing of case shown in Fig. 16-A to show calculation of equalization of limb length.

fits accurately along the femoral shaft. The plate is then clamped into position and fixed with screws.

The window is now cut in the trochanteric region, in order to allow removal of fibrous tissue from the fracture plane and curettage into the head of the bone for the reception of the graft from the crest of the ilium [13]. After closure of the capsule, replacement of the muscles, and suture of the wounds, the limb is removed from the stirrup. While the knee is still bent, several firm blows are administered to the knee to assure impaction at the fracture sites.

The limb is now fixed in balanced traction in a Thomas splint. The patient remains in the splint for six weeks, and, during this period, is encouraged to move freely in bed. Treatment after the operation is practically the same as that given after an intertrochanteric fracture in which a blade plate has been used for internal fixation. The author believes that there is a distinct advantage in avoiding external fixation in plaster, especially in the elderly patient, since some movement is helpful in promoting general well-being. While the patient is in balanced traction, quadriceps exercises are encouraged; these tend to

THE HIGH GEOMETRIC OSTEOTOMY, WITH ROTATION AND BONE GRAFT, FOR UNUNITED FRACTURES OF THE NECK OF THE FEMUR

A Preliminary Report *

BY JAMES A. DICKSON, M.D., CLEVELAND, OHIO

From the Cleveland Clinic, Cleveland

In planning the treatment for ununited fractures of the neck of the femur, orthopaedic surgeons have come to think in terms of a bone-grafting procedure *versus* an osteotomy. This "either-or" viewpoint has been expressed, in a recent collective review [29] on the subject, as follows: "The condition may be relieved by the Albee bone grafting operation, or a modification of this procedure by the insertion of internal fixation in addition to the bone graft. The alternative is to perform one of the various types of osteotomies that have been recommended."

The fact that two schools of thought exist as to the best treatment for ununited fractures of the femur is sufficient evidence that neither procedure in itself is entirely satisfactory. Both procedures—bone-grafting and osteotomy—have produced satisfactory results in a certain proportion of cases, and both present certain advantages and disadvantages. The experience and preference of the surgeon has determined which method would probably offer the individual patient the best chance of obtaining a functioning hip.

Bone-grafting procedures, either alone or together with internal fixation, have been described by Albee, Henderson, Gallie, Compere, Campbell, and the author. These procedures rely largely upon the stimulation of osteogenesis to procure union. In the various types of osteotomy, as devised by Schanz, McMurray, and Leadbetter, and as reported by Schumm, Speed and Smith, Blount, Reich, and others [12, 18, 19, 21, 25, 27], attention has been focused on the correction of faulty mechanics. Although osteotomy has produced satisfactory union in some cases, there have been others in which union did not occur, despite correction of the mechanical difficulty at the fracture site. In a series of thirty patients who were subjected to osteotomy by Speed and Smith, solid osseous union was obtained between the head and the neck of the femur in only fifteen. These authors have commented that, "Although functional results are better if union takes place between all three fragments, or between the head and neck, satisfactory function ensues even though nonunion between the head and neck persists, since the new mechanics of the hip have eliminated shearing force at the fracture site, established a bony support, and provided an improved line of weight-bearing".

The Brackett operation [4], which also aims at correction of faulty mechanics, is still favored by some orthopaedic surgeons [24, 30]; but the author is in accord with the opinion of Watson-Jones that this operation is not to be recommended, because the extensive dissection required produces much greater interference with circulation than does osteotomy.

It has been well established, in the treatment of non-union or delayed union elsewhere in the skeletal system, that good mechanical factors, combined with the use of transplanted bone, yield the most satisfactory results. In studying the problems presented by ununited fractures of the neck of the femur, and in considering the advantages and disadvantages of the various procedures now being used, it seemed desirable that a suitable operation be devised which would combine the advantage of corrected mechanics, obtained by osteotomy, with that of the improved osteogenesis, produced by a bone graft.

* Outline presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1946. Scientific exhibit presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1947.

Fig. 17-A

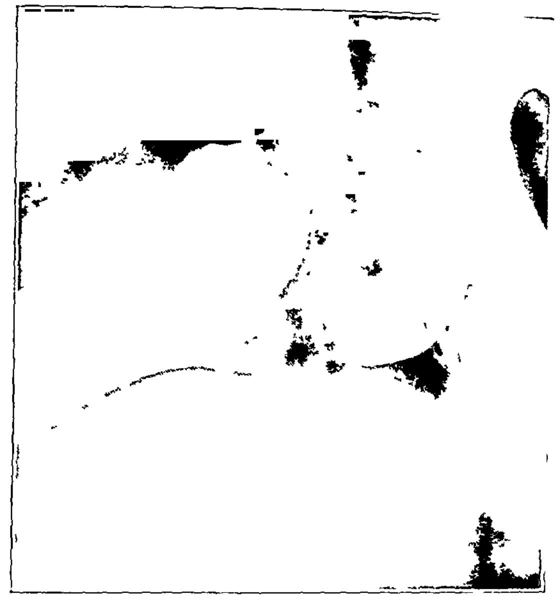

Fig. 17-B

Case 1. Preoperative anteroposterior and lateral roentgenograms, showing non-union.

(Figs. 18-C and 18-D). The patient had a full range of motion in the hip, and his limbs were of equal length.

Case 3. A woman, aged seventy-five, slipped on a cement floor and injured her right hip on April 4, 1945. Roentgenograms were made at the time of the injury, but were reported as showing no fracture. When she was seen, three months after the injury, there was severe restriction of motion in the hip joint, with one inch of shortening of the extremity. A roentgenogram revealed an ununited fracture of the neck of the right femur (Fig. 19-A). Operation was performed on August 9, 1945, and balanced traction was applied until September 27. Roentgenograms made nine months after operation showed union of the fracture (Figs. 19-B and 19-C). The patient had an excellent range of joint motion, and was walking well, with limbs of equal length

DISCUSSION

Despite the great improvement in the results of treatment of acute fractures of the neck of the femur, since the advent of the method of internal fixation[33], non-union results in approximately 20 per cent. of cases,

Fig. 17-C

Fig. 17-D

Anteroposterior and lateral roentgenograms eight months after operation.

to break down the fibrous scar tissue, and there is no opportunity to use grafted bone to facilitate union.

Neither osteotomy nor a bone-grafting procedure restores the loss of limb length which almost invariably is present with ununited fractures of the femoral neck. In the literature, emphasis has been placed almost entirely on obtaining a stable weight-bearing hip, and results are reported as satisfactory, provided that good joint function has been procured, even though there may be one to two inches of shortening of the limb. In the series of thirty cases reported by Speed and Smith, the average shortening after osteotomy was 1.3 inches. Leadbetter, in one of his last contributions, convincingly demonstrated that, with the high osteotomy, greater limb length was obtained than with other types of osteotomy. However, except in early cases, in which the operation was performed

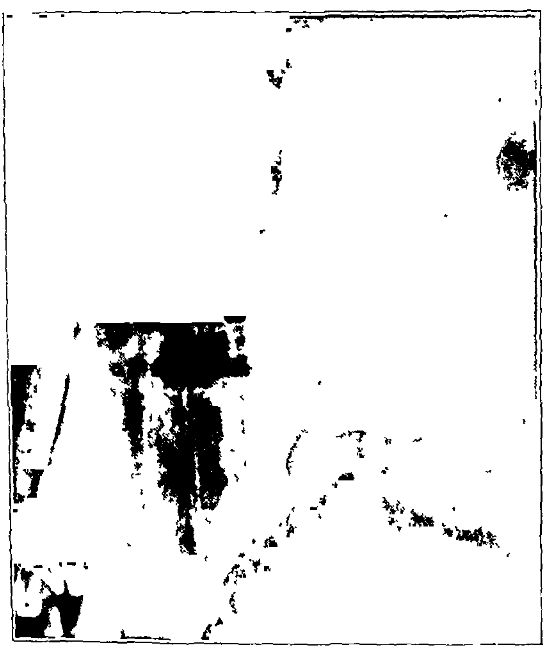

FIG. 3

Roentgenogram of a typical ununited fracture of the femoral neck.

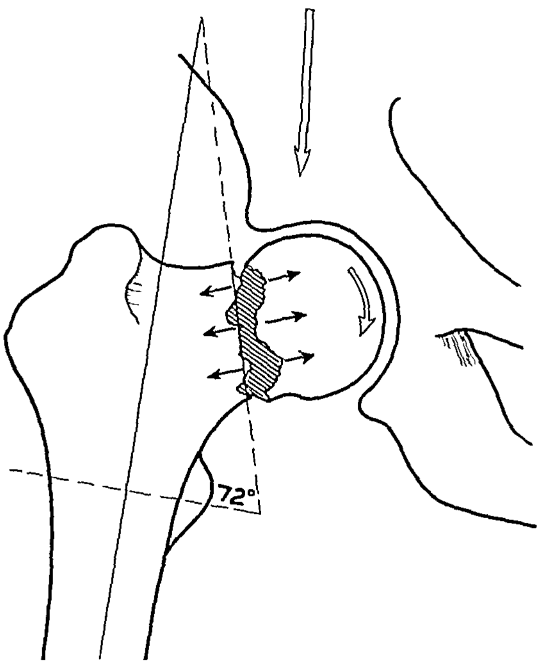

FIG. 4

Mechanical analysis of the fracture shown in Figure 3.

before very much fibrous scar tissue had developed at the fracture site, it was the author's experience that Leadbetter's procedure was carried out only with considerable difficulty.

In analyzing roetgenograms of ununited fractures of the neck of the femur, the femur should always be in internal rotation to reveal the true length of the remaining neck and the inclination of the fracture plane. A review, by the author, of many cases has shown that invariably there has been a downward rotation of the head of the femur, within the acetabulum, of about 60 degrees, and that the plane of fracture has been almost vertical, or, in the terminology of Pauwels or Linton, would fall in the third group (Figs. 3 and 4). It seemed evident on all roentgenograms studied that, if the upper part of the trochanteric region and the head of the femur were rotated 60 degrees, the head of the femur would assume its normal relationship within the acetabulum, and the mechanical stress on the fracture line would be changed, so that the fracture could be classified as in the first group and would have the advantage of impaction to stimulate union.

THEORETICAL TECHNIQUE

After consideration of the above data, the conclusion was reached that an improved technique for the correction of ununited fractures of the femoral neck should consist of a high osteotomy, which would allow a 60-degree rotation of the head and the trochanteric

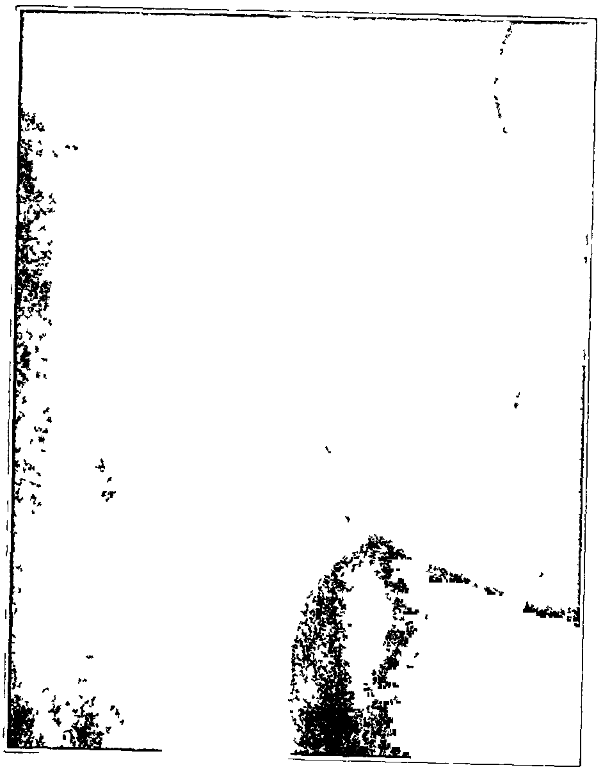

FIG. 19-A

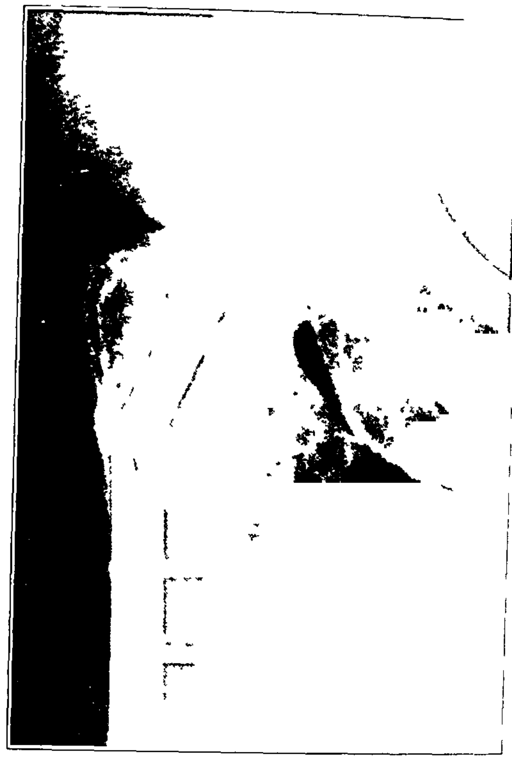

FIG. 19-B

Fig. 19-A: CASE 3. Preoperative anteroposterior roentgenogram, showing non-union.
Fig. 19-B Anteroposterior roentgenogram nine months after operation.

FIG. 19-C

Lateral roentgenogram nine months after operation.

(1) In addition to accurate control in correcting the mechanical defects and (2) to stimulating osteogenesis by use of a bone graft (thus counteracting the two factors most disadvantageous for bony union), the operation also has the following virtues: (3) Equalization of limb length is procured; (4) muscular attachments to the trochanter are not disturbed, and thus the muscles and ligaments are in good position for normal walking; (5) no extensive dissection is required which would cause additional interference with the blood supply to the femoral head and neck; (6) the surgical procedure is not particularly productive of shock; (7) there is no need for external fixation in a cast; and (8) the postoperative care is simplified, involving no greater difficulty than treatment of a simple intertrochanteric fracture in which internal fixation has been used.

It is not as yet definitely established what part the obliquity of the fracture line plays in the development of pseudarthrosis. The fact that, in the cases here presented (in which non-union had persisted for approximately two to three years), bony union was procured after correction of the mechanics is suggestive that this factor is extremely important. Although the author has had no opportunity to apply this geometric osteotomy in treatment of acute fractures, it seems probable that the principles utilized in the treatment of ununited fractures may later be applied in carefully selected cases to prevent non-union. If the possibility of non-union is recognized early, and if the operation is carried out

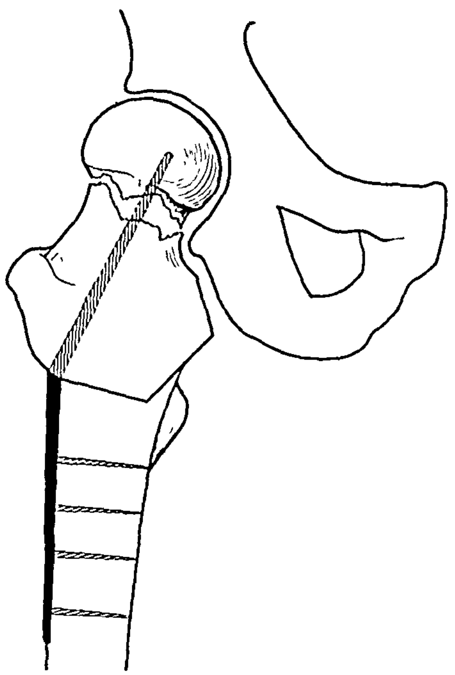

FIG. 8

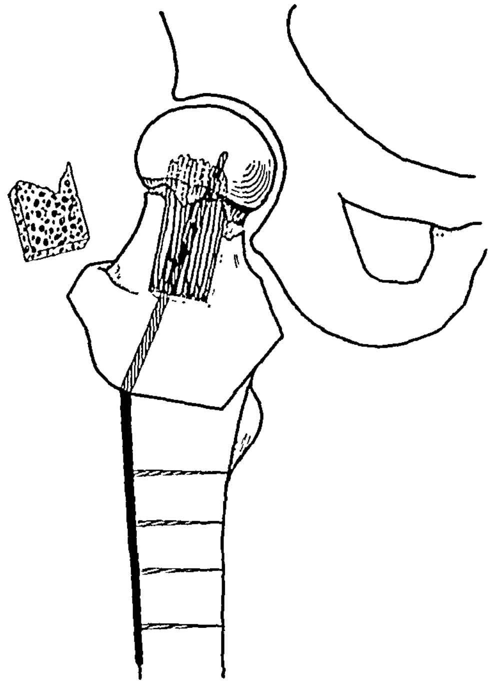

FIG. 9

Fig. 8: Drawing showing rotation of the femoral head and the trochanteric segment, and the fixed position of the blade plate.
Fig. 9: Drawing showing the bone grafts in place.

was necessary to devise a hexagonal marker in which the long diameter of the hexagon equalled the distance from the lateral prominence of the trochanter, where the blade plate entered, to the upper surface of the lesser trochanter (Fig. 5). Then, by placing this six-sided marker on the anterior surface of the femur, with one side parallel to the flare of the trochanter as it extends downward from the site of entrance of the blade plate, it would be possible to determine the exact site for osteotomy (Fig. 6). (In practical application, a semihexagonal chisel is used for this purpose [Fig. 14].) If a marker of the proper size were used, it is obvious that the lower medial edge of the marker would always come out just above the lesser trochanter, thus assuring a high osteotomy. If the upper transfixed fragments were then rotated so that side *A* would be brought into the position of *A′* (Fig. 7), an accurate rotation of 60 degrees would be assured; the blade plate would assume its proper position along the shaft of the femur; and a stable contact of the fragments, with a perfect fit, would result (Fig. 8).

To complete the operation, a bone-grafting procedure, designed to ensure osteogenesis, could be readily accomplished by first removing a window from the trochanteric region, and, after thorough curettage of the fibrous tissue from the old fracture site and well up into the head, multiple bone grafts from the ilium could be impacted into the head and neck of the femur, according to a method previously described [13] (Fig. 9).

PRACTICAL TECHNIQUE

The technique used in translating this plan into practice can probably be described best by following the steps as carried out in an actual case.

When necessary, adhesive traction is applied for a few days before operation, to bring the stump of the neck of the femur opposite the head of the bone. In the cases so far encountered, this has been quite satisfactorily accomplished. Some time during the preliminary investigation and preparation, a blade plate of known size is strapped onto the side of the thigh opposite the trochanter, and roentgenograms are made to permit definite calculations as to the actual size of the bone; this determines the dimensions of the blade plate and the marker or chisel which will be used at the operation (Fig. 10).

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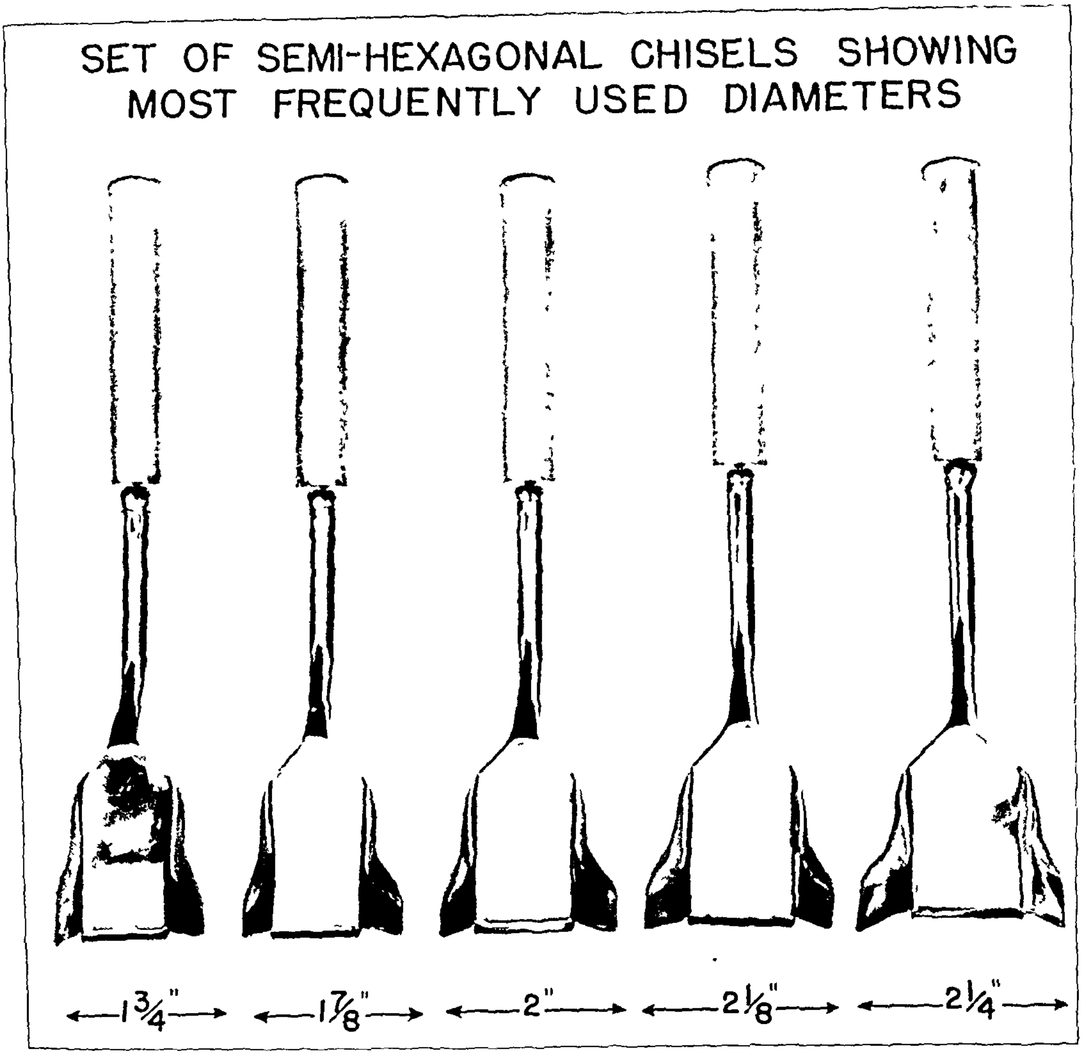

FIG. 14

Set of five semihexagonal chisels for marking the site of osteotomy.

outward, with medial reflection of the muscles anterior to the femur. This allows adequate exposure with a minimum of interference with the blood supply. A guide wire is then passed from a point about one-half inch above the prominence of the greater trochanter into the center of the head of the femur (Fig. 11). Roentgenograms are made in order to check the position of the wire and the length of the blade which will be necessary. The proper blade plate is then selected, and is bent so that, when the blade is inserted parallel to the guide wire, the plate will project from the femur at an angle of 60 degrees (Fig. 12). This angle is procured by use of a protractor [3] which fits along the shaft of the femur. The blade plate is inserted so that a good hold is obtained on the head of the femur (Fig. 13), and the fracture plane is well impacted, and the blade is securely fixed. The lesser trochanter is now palpated, and the distance from the prominence of the greater trochanter, where the blade plate enters, to the lesser trochanter is calculated with a caliper. A semihexagonal chisel, with a diameter of this width, is chosen from the set of five chisels with diameters varying in width by one-eighth of an inch from one and three-quarters inches to two and one-quarter inches (Fig. 14). The chisel selected is then used to mark the site of the osteotomy. One side of the chisel extends down, parallel to the lateral aspect of the femur, from the point of entrance of the blade plate. The line of osteotomy is marked along the other two blades. The osteotomy is completed with an osteotome. The upper end of the trochanter and the head of the femur are then rotated downward, while the femur itself is brought into slight abduction with traction, until the blade plate

aid impaction of the ununited fracture and at the osteotomy site, and thus help to stimulate bone repair.

EQUALIZATION OF LIMB LENGTH

This type of high osteotomy tends to re-establish a femoral neck, and it increases the limb length from three-quarters to one and one-half inches in the adult of average size. Fortunately, the greater the varus deformity and shortening, the greater the increase in limb length obtained after operation (Figs. 15-A and 16-A). The increase in length can be accurately calculated (Figs. 15-B and 16-B). Rotation takes place about the center of the head of the femur, and the radius of the circle of rotation, designated as R, is equal to the distance from the center of the head of the femur to the center of the hexagon on the trochanteric segment. The degree of varus is determined by the angle that R makes with the perpendicular to the long axis of the femur. When these data are known, the increase in length that will be obtained, when rotation is accomplished, can be calculated by the following formula:

X stands for the increase in limb length.

$$X = R\ (\text{Sine of angle after rotation} - \text{Sine of original angle})$$

The sine values are constant and are easily obtained from tables on the values of trigonometric functions.

In the case shown in Figures 15-A and 15-B, in which a moderate varus position of 30 degrees is present before rotation, the increase of limb length would be calculated as follows:

$$X = R\ (\text{Sine } 90° - \text{Sine } 30°)$$
$$X = R\ (1 - 0.5)$$
$$X = R \times 0.5$$

In the case shown in Figures 16-A and 16-B, in which there is an extreme varus position of 10 degrees before rotation, the increase of length would be as follows:

$$X = R\ (\text{Sine } 70° - \text{Sine } 10°)$$
$$X = R\ (0.9397 - 0.1736)$$
$$X = R \times 0.7661$$

Thus, in practical application, the rotation of 60 degrees results in restoration of normal limb length.

CLINICAL RESULTS

The clinical results in three cases in which the procedure of high geometric osteotomy, with rotation of 60 degrees and bone-grafting, was performed for ununited fracture of the neck of the femur are presented:

Case 1. A man, aged forty-two, fractured his right hip in July 1944. He had been treated with supracondylar traction with a Steinmann pin for three months, and then was in a plaster spica for six months. When he first consulted the author, a year and nine months later, there was an ununited fracture of the neck of the right femur, with one and one-half inches of shortening in the limb (Figs. 17-A and 17-B). Operation was performed on May 15, 1946, and balanced traction was applied until June 22. He was walking on crutches in July. Eight months after operation (Figs. 17-C and 17-D), roentgenograms were made which showed that bony union was complete. The patient's lower extremities were of equal length, and he had a full range of motion in the hip joint.

Case 2. A man, aged fifty-eight, fractured his right hip in February 1943. Internal fixation with a Smith-Petersen nail was instituted four days after injury. Since then, he had not been able to walk without crutches. When he was first examined, on April 17, 1946, three years and two months after the injury, roentgenographic study showed an ununited fracture of the neck of the right femur, with one and one-quarter inches of actual shortening of the limb (Figs. 18-A and 18-B). Operation was performed on July 11, 1946, and balanced traction was applied until August 24. The patient was on crutches two weeks later. When he was seen six months after operation, roentgenograms showed that bony union was taking place

Fig 18-A

Fig. 18-B

Figs. 18-A and 18-B: Case 2. Preoperative anteroposterior and lateral roentgenograms, showing non-union.

Figs. 18-C and 18-D: Anteroposterior and lateral roentgenograms six months after operation.

Fig 18-C

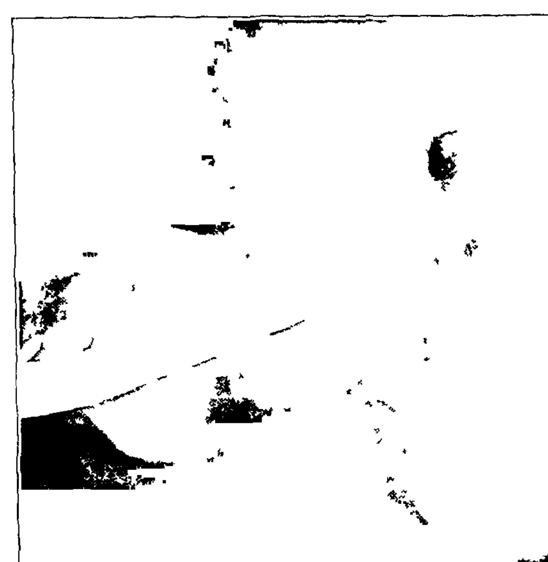

Fig. 18-D

regardless of the type of internal fixation used. The majority of these cases of non-union occur in fractures of the shearing type, in which, as Pauwels has emphasized in his classification of femoral-neck fractures, the plane of the fracture is relatively vertical,—that is, 50 to 90 degrees. By the use of the high geometric osteotomy here described, with rotation of the fragment through 60 degrees, this angle is reduced to 30 degrees or less; thus shearing stress is relieved, and the fracture becomes stable and in the optimal position for bone repair.

By thus correcting the mechanical defect contributing to the non-union, and by further ensuring bony union through use of a bone graft, this method offers definite advantages over those previously employed. Although the procedure has been used in only ten cases—and in some of these the operation has been performed too recently to allow final conclusions—the results so far achieved indicate that actual experience will confirm these advantages.

before advanced degenerative changes have occurred, satisfactory union can be expected, with avoidance of many secondary plastic, reconstruction operations.

Linton, after a thorough analysis of 365 cases of fracture of the femoral neck, concluded that "primary osteotomy in connection with reduction and nailing is indicated in cases with a very steep fractured surface . . . or when, for some reason or other, reduction and nailing have failed". He used a wedge osteotomy as a primary procedure in four cases of the former type; union was obtained in all. The type of osteotomy described in this paper would probably have the same advantages over the wedge osteotomy, for this type of fracture, that it has in old ununited fractures. In acute fractures, the additional feature of the bone graft may not be necessary.

It would seem desirable that additional studies should be made to determine the importance of the angle of the fracture plane in relation to non-union of femoral-neck fractures, and that attempts should be made to prevent pseudarthrosis by attention to this factor. If, by proper selection of cases, osteotomy as a primary procedure could prevent the majority of cases of non-union, this would constitute a distinct advance in orthopaedic practice, and would be a great boon to many patients with fractured hips, by minimizing a long period of incapacity and hospitalization.

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